X. Description and Efficacy of common Chiropractic radiographic views

RECOMMENDATION

The 19 common Chiropractic Radiographic views and the motion assessment procedures are indicated for the routine qualitative and/or quantitative assessment of the biomechanical components of vertebral subluxation. These radiographic views have reliability, validity, and clinical outcomes data that evidence their clinical utility in clinical chiropractic practice. When using these radiographic views and procedures, a baseline value of the mechanical component of spinal subluxation should be determined prior to the initiation of chiropractic treatment intervention. In this manner, response to care can be determined.

Supporting Evidence: AP Nasium, and Ferguson: Clinical Levels I-V. Other Radiographic Views: Clinical Levels II-V, Population Studies Class 1-4, Biomechanics, Reliability Studies Class 1 and 2, and Validity.

PCCRP Evidence Grade: Specific Grades will be given under each view.

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Introduction

There are numerous spine radiographic views that are utilized by both Medical Doctors and Chiropractors. Some radiographic views are unique to the medical profession for locating pathologies and fractures and some are unique to the chiropractic profession for locating and measuring spinal subluxations.

The PCCRP Guideline Panel has determined a set of radiographic views that are utilized in different chiropractic technique methods and by Chiropractors in general, for the assessment of spinal subluxation. After listing these radiographic views, there will be a discussion of each views clinical utility by breaking the discussion of the literature into these topics:

- History of the view,
- Reliability of patient positioning for the view,
- Reliability of measurements for spinal subluxations,
- Validity of the particular view,[1,2]
- Outcome studies using conservative chiropractic treatment methods.

Some of the publishing DACBRs and Chiropractic academics have stated that there is little or no evidence for radiographic biomechanical assessment of spinal subluxations.[3,4] In addition to providing Level V (opinion) evidence, some DACBR's, Chiropractic academics, and MCO's often refer to 'selective' literature and often mis-represent certain studies.[3-5]

For example, the 2001 study by Gore[6] is often used to support the contention that radiography lacks predictive validity. Of interest, the study by Gore[6] actually supports the predictive validity of spinal radiography, in as much as Gore[6] found that cervical spine degenerative joint disease in the mid-lower cervical spine predicted which subjects (initially asymptomatic) developed cervico-genic symptoms at minimum 10-year follow-up. Gore[6] did not report the cervical lordosis variables for subjects who did versus those who did not develop cervico-genic symptoms, instead he offered Level V evidence.[7] Problematically, chiropractic advocates[3-5] continue to use the study by Gore[6] to claim the cervical lordosis lacks predictive validity.

As a last point to address, many Chiropractic academics use one-sided arguments in their push to limit the chiropractic clinician's use of spinal radiography. For example, Whalen[8] places the burden of radiography validity on the practicing chiropractor and techniques when he stated, "*The promoters of certain techniques who have positioned themselves reliant on x-ray, like the rest of us, are obligated to produce the evidence to show that it makes a difference either (a) in terms of increased risk from treatment that provides good benefit if the x-rays are not taken and/or (b) that taking the images makes any difference in outcome over treatment without the x-rays.*"

However, it is the position of the PCCRP panel that because the majority of chiropractic clinicians use radiography (see Section III and IV) to determine contraindications to specific interventions, spinal subluxation type (as defined in Section V), and exact treatment intervention, then the burden of proof should be placed on those who would like to limit radiography in chiropractic. In other words, Whalen[8] and others are responsible for demonstrating that patient safety and outcomes are the same when radiography is not used compared to when it is used for specific chiropractic interventions for all possible patient presentations. Unfortunately, there is no evidence showing improved or equivalent outcomes when spinal radiography is not used in chiropractic clinical practice compared to when it is used. Therefore, radiography is the standard.

Radiographic assessments can be considered valid if they precisely reflect certain characteristics or they can accurately predict future outcomes or have strong correlation to a particular pain, disease, or health disorder.[1,2] In truth, there is a plethora of information in the literature supporting radiography for assessment of spinal subluxations. We have decided to provide this evidence for the radiographic views utilized in different Chiropractic Techniques.

We have placed chiropractic radiographic views into classifications by the region visualized on the film, i.e., cervical, thoracic, lumbar, pelvic, full spine, stress/bending films, and motion x-ray for trauma. These radiographic views include, but are not limited to:

A. Cervical Views
   1. AP Cervical/Cervico-Thoracic
   2. Nasium
   3. APOM
   4. Blair Protracto Views
   5. Vertex
   6. Base Posterior
   7. Lateral
   8. Sagittal Translation Stress/weighted View
   9. Flexion/extension

B. Thoracic Views
   10. AP
   11. Lateral

C. Lumbar Views
   12. AP
   13. Lateral
   14. Flexion/extension

D. Pelvic
   15. AP Fergusson
   16. AP (short leg/femur head view)

E. Full Spine

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17. AP
18. Lateral
19. Bending and/or stress films for the assessment of scoliosis or buckling

F. Motion X-ray for Trauma Evaluation

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A. Cervical Views

1. AP Cervical/Cervico-Thoracic

RECOMMENDATION

The AP Cervical or Cervico-Thoracic Radiographic view is indicated for the routine quantitative assessment of the biomechanical components of vertebral subluxation. This radiographic view has reliability, validity, and clinical outcomes data that evidence its clinical utility in clinical chiropractic practice. When using this radiographic view a baseline value of the biomechanical component of spinal subluxation should be determined prior to the initiation of chiropractic treatment intervention. In this manner, response to care can be determined.

<u>Supporting Evidence</u>: Clinical Levels II-V, Population Studies Class 2 and 4, Biomechanics, Reliability Studies Class 1 and 2, and Validity.

<u>PCCRP Evidence Grade</u>: Clinical Studies = B, C, D.

Introduction

The AP Cervical view provides better visualization of the upper thoracic and mid to lower cervical alignment. This projection also allows better visualization of any pathologies and anomalies that are present.

The AP Cervical projection is taken at a focal film distance of 40 inches with a 15 degree cephalad tube tilt. The central ray (CR) is directed through the mid cervical region[13] or CR at T1 by CBP Technique in order to visualize the upper thoracic spine's compensation to cervical posture. This view can be taken standing or seated using a stool or positioning chair. The patient is positioned with their back against the grid cabinet with the frontal plane of the thorax parallel to the cabinet. The positioning of the grid cabinet is to include C2 superiorly and at minimum T2-T3 inferiorly.[13] (Figure 1)

Measurements are made on the AP Cervical view in millimeters and in degrees for disturbances of the vertical coronal alignment.[3] (Figure 2)

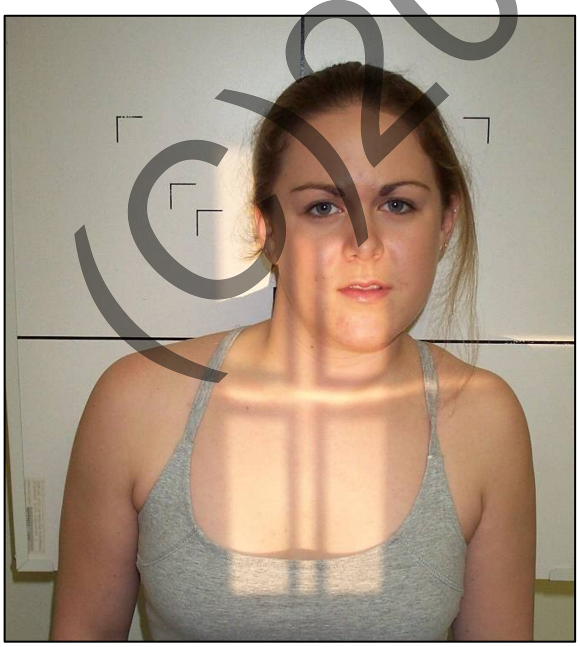

Figure 1. AP cervicothoracic radiographs are obtained with the patient sitting/standing with his/her shoulders centered against the cabinet. A 10x12 in. cassette is generally used with central ray at the mid-lower cervicals and for visualization of the upper thoracic spine.[12] If mid thoracic spine down to T6/7 is needed then it can be taken on a 7x17 in. cassette as depicted. This increased visualization of the upper thoracic spine is to see possible thoracic compensation due to cervical spine abnormalities. The patient positioning should be accomplished through small movements of the patient's feet and <u>NOT</u> by altering the patient's posture.[2]

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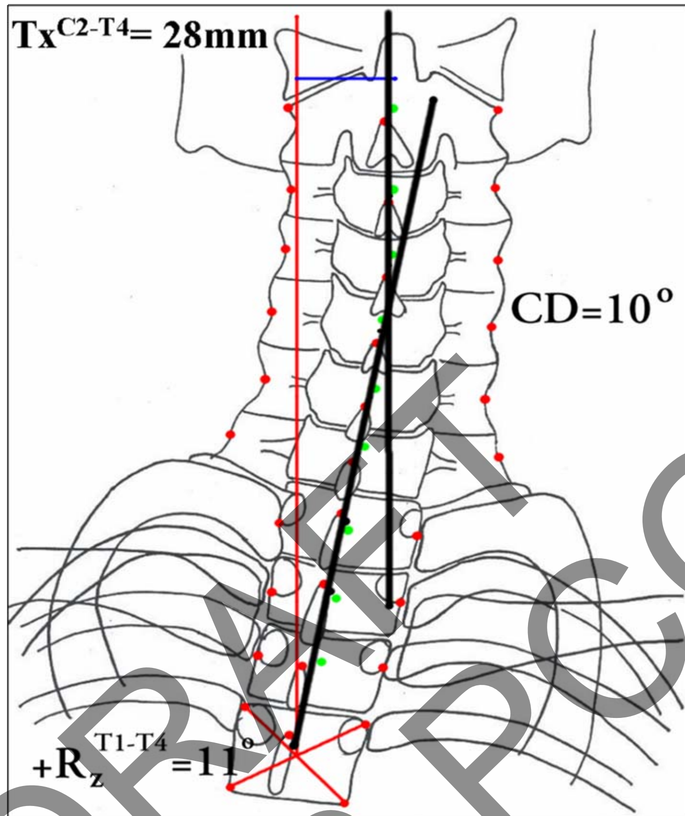

Figure 2. Harrison's modified Risser-Ferguson method applied to AP cervical radiographs. As an alternative to the Cobb analysis of scoliosis, the Risser-Ferguson approach uses the centroids of the end points and apex of a scoliosis. Centroids are determined by the intersection of the vertebral body diagonals. Harrison modified this approach on AP radiographs by bisecting the narrow-waisted lateral vertebral margins, which in the cervical spine are points on the articular pillars.[3] Besides an angle at the apex of the scoliosis (CD angle), a lateral flexion angle (Rz) of the upper thoracic spine can be calculated.

Many chiropractic techniques use AP cervical views, along with lateral cervical views, to determine the course of care for the patient. This determination includes patient positioning for the adjustment where the pre-manipulative force is applied, as well as what line of drive will take place. This adjustment is usually manual, but a hand-held instrument can substitute for the manual line of drive. These same techniques require that a post-treatment x-ray be obtained to validate, objectively, a successful course of treatment (i.e., reduction of head translation in millimeters, reduction in the CD or other angles, thus reduction of the subluxation misalignments and angle of lateral bending of T1-T3 compared to vertical).

Reliability of Line Drawing Methodology

The measurements on the AP cervical view have been subjected to scrutiny by many within the chiropractic profession. In the medical literature, Cobb angle analysis has been the method of choice for measurement of levo- and dextro-scoliosis on anteroposterior radiographic

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views.[6] In 1995 Skalli et al[10] evaluated the Y-axis rotations-methods of AP radiographs and they determined that the pedicle method of Drerup[1] has high reliability.

In 2001, Janik et al[11] reported on a method to measure lateral flexion and axial rotation coupled motions on AP cervical radiographs. They studied these parameters on AP Cervical radiographs in two methods, one axial rotation of a C3 model and on radiographs of 30 subjects with 3 examiners, who evaluated the 30 radiographs twice. On the model, the method had an error of less than 0.75°. For lateral flexion, they reported ICCs > 0.86 (high range) and for axial rotation, they reported ICCs > 0.67 (good & high range).

Finally, chiropractic biophysics digitized radiographic mensuration analysis of the AP cervicothoracic view showed correlation coefficient values >0.70. These values are considered excellent for use in clinical and research operations.[3,12,13]

Reliability of Patient Positioning

Huggare[7] performed a study analyzing neutral head posture on posterior to anterior radiographs using a sample population of twenty-two. Huggare concluded that "frontal head position is more accurately reproducible than the sagittal head position."[7] Harrison et al[4] investigated the repeatability of AP cervical radiographic positioning and analysis in 23 control subjects with chronic neck pain. The mean follow-up time between repeat radiographs was 11.7 months and different examiners were used on initial versus follow-up radiographs. All angles and distances changed less than 1° or 1mm and all P-values were reported as not statistically significantly different (P>0.05).

Diagnostic Capabilities

The AP cervical view demonstrates the best visualization of the lower six cervical vertebrae (especially vertebral bodies, Von Luschka joints, and spinous processes), the upper three thoracic vertebrae and ribs, medial border of the clavicles, lung apices, trachea, and neck muscles.[14] Suspended expiration is also recommended during the x-ray processes.

Validity

Investigations have found positive correlation and validity of the AP cervical radiographic alignment to the following health related conditions including:

1. Chronic neck pain duration and intensity,[8]
2. Whiplash associated disorders (WAD),[15]
3. Degenerative joint disorders of the mid and upper cervical spine.[16]

In a retrospective examination of 335 AP cervical radiographs of patients screened for lateral head translations ≥5mm, Oakley and Harrison[8] identified 176 (53%) patients with this AP cervical subluxation. Of these, 146 patients (67 male; 79 female) had head/neck complaints. Thirty-eight percent of neck pain patients (56/146) had left head shifts while 62% (90/146) had right head shifts. The typical pattern was an upper thoracic lateral flexion angle toward, and a mid-neck angle away from, the side of head lateral translation. Those with left head shifts suffered from pain longer but had smaller absolute mid-neck angles. Significant correlations existed between patient age and pain duration, pain duration and head translation distance, absolute head translation distance and age and absolute mid neck-angle and neck disability index (NDI) score.

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In 1960, Zatzkin and Kveton[15] reported the AP cervical spine radiographic findings of 25 men and 25 women involved in a motor vehicle accident (MVA) and compared their results to 35 normal controls (25 men & 10 women) with no history of trauma or symptoms related to the cervical spine. They found significant differences between the two groups in AP cervical radiographic alignment; where the whiplash group had AP cervical scoliosis present in 46% of subjects versus only 9% of the Control subjects.

Another investigation found conflicting results where the AP cervical alignment measurements did not correlate to acute and chronic neck pain.[17] Yi-Kai et al concluded that AP cervical alignments are not different between of 87 neck pain patients compared to 21 controls. Problematically, acute (1 day duration) and chronic (4 years duration) neck pain subjects were lumped together by Yi-Kai et al[17] in their analysis and no measurements of the AP cervical alignment were performed accept the C1-C2 joint space alignment (this is discussed further under the APOM View). Therefore, the study by Yi-Kai et al[17] has serious methodological flaws and does not apply to the alignment of the AP cervical radiographic view other than the C1-C2 left/right joint space.

Biomechanical Validity

There are several types of validity. Construct and predictive validity are applicable in clinical situations as just previously discussed, while a second type, we term "Biomechanical validity". For this second type of validity, the clinician compares the spinal coupled motions on the AP cervical radiograph to the published results of "main motion coupled motion" performed on head postural movements. If the usual coupled motion patterns on AP cervical radiographs are not present for a particular head posture, the clinician is alerted to the fact that either anomalies or spinal injuries are present.

Several main motion/coupled motion investigations have been reported for head movements and AP cervical radiographic patterns. In a series of original publications, reviews and texts, Harrison et al[18-21] have outlined the cervical coupling movement for the head postures of:

1. Head axial rotation
2. Head lateral bending
3. Lateral Head Translations.

It is the consensus of the PCCRP panel that the quality of investigations finding a correlation between AP cervical radiographic alignment and the conditions in the above 3 categories is superior to the one negative correlation study. Thus, we conclude that the AP cervical radiographic alignment has positive correlation and validity for these 3 categories.

Outcome Investigations

Level I studies: No level I studies could be located.

Level II studies: Harrison et al[4] reported on fifty-one patients, with chronic neck pain and lateral head translation posture (side shift), who received Mirror Image opposite postural exercises, drop table adjustments, and opposite postural traction. The treatment subjects were compared to a control group of twenty-six subjects with lateral head translation posture and chronic neck pain. Radiographic measurements and pain scales were compared at initial and follow-up for

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treatments subjects (at 12 weeks and 37 visits) and control subjects (at 50 weeks and no treatment). Radiographic subluxation of the AP cervical spine was used to determine treatment. No statistically significant changes were observed for control subjects' pain and radiographic measurements, while treatment subjects showed statistically significant improvements in AP cervical radiographic measurements of head translation posture and pain.

Level III studies: No Level III studies could be located.

Level IV studies: Harrison, Harrison and Haas[5] reported on AP cervical radiographic alignment, pain and disability improvements in 5 cases following CBP Mirror Image rehabilitative methods directed at reduction of AP cervical subluxations.

Oakley and Harrison[9] reported on the successful reduction of AP cervical radiographic subluxations and consequent improvements in pain, disability, and health status following CBP Mirror Image rehabilitation of a 57 year old female with chronic, post-surgical, cervical spine pain and impairments.

Bolton and Bolton[22] reported the successful management of 3 cases with acute cervical torticollis pain and impairments using the toggle recoil adjusting methods. The direction and side of the thrust was determined by AP radiographic alignment.

Moore[23] described the management of a patient with upper crossed syndrome and cervicogenic headache using a multi-modal chiropractic approach including specific diversified adjustments to the cervical spine, myofascial release, and exercise. Importantly the alignment of the cervical spine on radiograph was an important determinant of treatment and improved alignment was found on follow-up.

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2. Nasium Radiographic View

RECOMMENDATION

The AP Nasium Radiographic view is indicated for the routine quantitative assessment of the biomechanical components of vertebral subluxation. This radiographic view has reliability, validity, and clinical outcomes data that evidence its clinical utility in clinical chiropractic practice. When using this radiographic view a baseline value of the biomechanical component of spinal subluxation should be determined prior to the initiation of chiropractic treatment intervention. In this manner, response to care can be determined.

Supporting Evidence: Clinical Levels I-V, Population Studies Class 2, Biomechanics, Reliability Studies Class 1 and 2, and Validity.

PCCRP Evidence Grade: Clinical Studies = A, B, C, D.

Introduction

The AP nasium (or just Nasium) upper cervical radiographic view was originated by A.A. Wernsing, DC in 1930.[1,2] This view can be taken standing or sitting on a specifically designed positioning chair, which can be mechanically moved in various directions by the x-ray technician. (**Figure 1**)

This view requires a little more work in equipment and positioning time compared to an AP open mouth or an AP cervical view. The specialized equipment includes a tilting grid cabinet, a tiltable x-ray tube, an x-ray frame that will allow the tube and grid cabinet distance to be less than 40 inches, and precision head clamps with a centering glabella rod. Grostic was the first to add the precision head clamps and positioning chair for precise positioning in this radiographic view.[3-7] A lateral cervical x-ray must be obtained of a subject in order to determine the tilt and height of the x-ray tube compared to the subject's facial features. This tilt and tube height is derived from the atlas plane line on the lateral cervical view. On the lateral view, a line through the atlas is compared to horizontal and given either an "S-Line" designation (1 SL = 10º) or is just measured in degrees.

Measurements are made on the nasium view in degrees. The skull is bisected using the edges of the parietal bones, while a line is drawn through the atlas (APL is drawn at the intersection of the inferior posterior ring and the lateral edges of the lateral masses). These two lines create the Upper Angle (UA). There are a few variations of creating a Lower Angle (LA), but in general it represents the path of projected centers of mass or centers of the neural canal from C2 to C7. **Figure 2** illustrates some geometric lines drawn on the nasium view.

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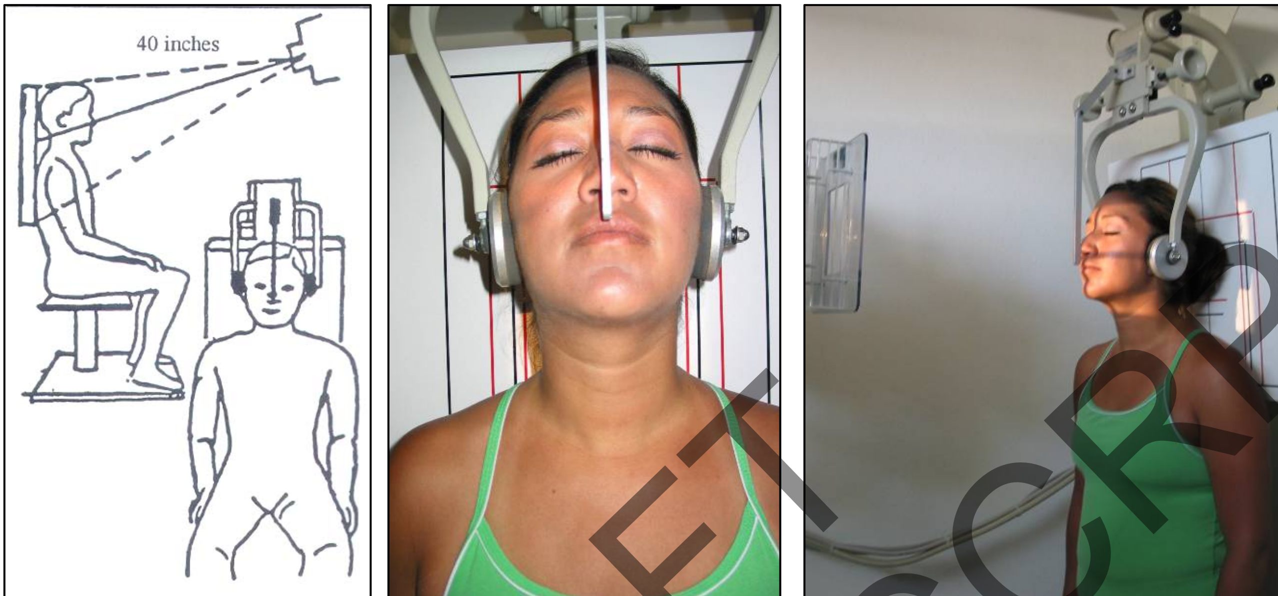

Figure 1 A-C. In A, a schematic showing the seated Nasium view with head clamps, glabella rod, tube tilt, tube height, and positioning chair. In B & C the standing Nasium radiographic view is shown with head clamps, glabella rod, tube tilt, tube height, etc…

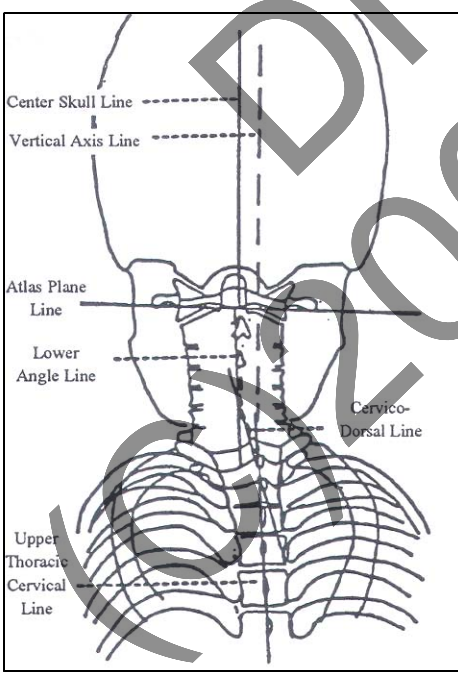

Figure 2. Nasium line drawing analysis. The UA compares the bisected skull to the APL, while the LA compares the APL to centers of vertebrae C2-C7.

Many Chiropractic Techniques (termed Upper Cervical Techniques) use measurements on the Nasium view to determine the care of a patient.[1-11] This determination includes how the patient is positioned for adjusting, where the adjustive force is applied, and what the line of correction (vector) will be. The adjustment can be manual or instrument assisted. Furthermore,

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these techniques require that a post treatment nasium x-ray be obtained to verify a successful intervention; i.e., a reduction in the subluxation misalignment of the atlas.

Reliability of Line Drawing Methodology

The measurements (UA & LA) on the Nasium view have been subjected to several reliability studies.[12-14,17,18,59,60-62] While a 1985 study[12] claimed poor reliability, Barker and Jackson[15] pointed out many methodological flaws in this 1985 study.

In a study using 38 Nasium x-rays and 3 examiners measuring each film on 2 occasions, Jackson et al[13] found excellent inter and intra examiner reliability; for both inter and intra-examiner reliability, Pearson's $r > 0.92$. Standard error of measurement for the upper angle (UA) was < 0.5º and for the lower angle (LA) it was < 0.8 º.

Rochester[14] reported excellent reliability with small standard errors of measurement (less than 1º).

Addington et al[59,60] found 80-90% agreement between examiners measurment of upper cervical subluxation on the Blair technique views.

In a study using 6 examiners marking 30 nasium x-rays, Jackson et al[17] found that reliability (stability over time) for the practitioners is very good. Reliability (equivalence over experts) across the practitioners is very good. The standard error of measurement for 6 examiners was 0.41° for the upper angle and .61° for the lower angle.

In a study of 38 sets of nasium x-rays taken before and after a sham adjustment, Jackson et al[18] found that all measures ≤ 1.0° indicating excellent reliability and small standard errors of measurement.

In a study using 1 nasium and 43 examiners, Seeman et al[61] found the mean difference was 0.55° for atlas laterality; 40% of the group was within 0.25 degrees of the and almost 75% were within 1 degree. Of importance, only 1/43 doctors found found laterality on the opposite side.

Spencer[62] compared the ability of experienced examiners and students to accurately measure the upper angle (atlas laterality) on the nasium x-ray. Atlast laterality on the nasium was found to have an inter-examiner error of 0.33°. Experinced doctors versus students did not affect the error margin.

Reliability of Patient Positioning

Reliability of patient positioning for the nasium view has been investigated in four separate reports.[16-19] Rochester and Owens[16] found that the average amount of patient to tube/film head axial rotation was 0.56° in twenty randomly pulled nasium films. They calculated that this amount of patient placement error for the nasium radiograph would only produce an average artifact in the atlas laterality of 0.21°.[16] Owens and Rochester concluded "…repositioning the patient for the post radiographic exam would not introduce significant error into the x-ray analysis…"[16]

In two separate investigations, Jackson et al[17,18] performed a repeatability study on the positioning for the nasium view and reported high reliability for a test-retest of patient positioning for the nasium view.[17,18] For example, in 2000, Jackson et al[18] obtained initial and repeated seated nasium x-rays in 38 subjects within four hours after receiving a sham adjustment. All measures were within 1.0° between initial and repeat radiographs; no statistically significant differences were found.

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Huggare[19] performed an investigation analyzing natural head posture on posterior to anterior skull radiographs of 22 dental students using a repeated measures design. This view is similar to the nasium view in as much as the skull is centered and upper cervical alignment is being analyzed. Two radiographs were obtained of each subject at a one-week interval. Cranio-vertical, cranio-cervical and cervico-horizontal angles were measured. The reproducibility (method error) of the cranio-vertical, cranio-cervical and cervico-horizontal angles were 1.15°, 0.93° and 1.45°, respectively. Huggare[19] concluded that the "frontal head position is more accurately reproducible than the sagittal head position".

Diagnostic Capabilities

Diagnostic usability is inherent on each radiographic view for the object on the central ray. Besides being the only view on which the atlas articulation with the head can be precisely measured, the nasium provides the best visualization of C1 and C2 of all the AP views. Additionally, the nasium view is quite similar in projection and positioning to the AP Towne's Projection medical view. The Towne's view is taken at 35^{o} caudal and the head is positioned without tilt or rotation. There are a multitude of boney objects visualized for normal anatomy on this view.[20]

Validity

Investigations have found positive correlation and validity of the AP nasium radiographic alignment. Radiographic studies have found validty for the following:

1. Headaches,[21]
2. 'Gold standard' method to measure atlas laterality.[22]

Ng[21] compared the upper cervical misalignments of 10 patients with headaches to 13 asymptomatic controls. The C1 laterality (UA) on the nasium demonstrated significant differences being 3.1° in patients and 2.0° in controls.

Eriksen[22] compared the validity of radiographical assessment of atlas laterality to 6 common non-radiographic methods that are used clinically to test for atlas subluxation (leg checks, palpation, thermography, etc…). Using the Kappa statistical test, Eriksen[22] found poor correlation between upper cervical x-ray analysis and the other analyses presented indicating that radiography is the only valid assessment for atlas subluxation alignment.

Biomechanical Validity

For biomechanical validity, the clinician compares the spinal coupled motions on the AP nasium radiograph to the published results of "main motion coupled motion" performed on head postural movements. If the usual coupled motion patterns on AP nasium radiographs are not present for a particular head posture, the clinician is alerted to the fact that either anomalies or spinal injuries are present.

In 1981, Harrison[8] reported on nasium images (Upper angles, lower angles, and CD angles) for the head postures of:

1. Head axial rotation
2. Head lateral bending
3. Lateral Head Translations.

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Outcome Investigations

A large number of studies have been performed using the nasium x-ray view to determine and quantify upper cervical subluxations and determine treatment intervention using upper cervical techniques in a variety of patient health disorders.[23-58,63-71]

Level I studies:

Brown et al[23] randomly assigned twenty subjects to either a Blair or a Grostic technique radiographic analysis and intervention to assess possible differences in initial atlas laterality, post-treatment correction, and patient improvements. Subjects completed a Rand SF-36 survey before and at the end of 4 weeks of care, to assess general health and quality of life. In 11/20 subjects (55%), atlas laterality was the same between the two techniques (kappa=0.08). Statistically significant improvements were observed between SF-36 scores pre and post care. No significant differences in change from baseline scores were observed between the two techniques.

In a radomized trial, Khorshid et al[24] assigned 14 autistic children to a full spine adjustment technique or the Atlas Orthogaonal upper cervical technique where radiography was used to determine the subluxation and adjustment. All subjects were evaluated using the Autism Treatment Evaluation Checklist (ATEC). Treatment duration was 3-5 months with monthly assessments including pre and post x-ray and leg length analysis. Improvement of ATEC scores was seen in 6/7 children under upper cervical care and in 5/6 under full spine adjustment. Average total ATEC improvement in the upper cervical group was 32%, while only 8.3% in the full spine group. Two autistic children under the upper cervical adjustment protocol no longer met the criteria to be considered autistic following the interventions.

Hoiriis et al[25] randomly assigned 26 chronic low back pain patients to 1 of 3 interventions: upper cervical analysis and treatment, full spine adjustments, and a combination of the two. In all groups, adjustment was determined by x-ray analysis, leg length, and palpation. Multiple outcome scales were kept and no group differences were detected; all groups improved.

Level II studies: No level II studies could be found.

Level III studies:

In 1999, Hoiriis et al[26,27] used a practice based research design to document the effects that upper cervical adjusting has on the Global Well Being Scale (GWBS) and the Rand SF-36 outcome measures scale in a patient population with predominant musculoskeletal complaints. Compared to initial measures, the 4-week outcomes showed statistically significant improvements in 6/8 of the SF-36 subscales. Whereas, compared to initial values, when the patient reached maximum chiropractic improvement statistically significant improvements in 7/8 of the SF-36 subscales were seen. They stated “Analysis of X-ray listings suggested that upper cervical chiropractic adjustment successfully reduced misalignment of the occipito-atlanto-axial complex”.[26,27]

Level IV studies:

There are a large number of case studies, case series, and cohorts without controls in the chiropractic literature utilizing the nasium x-ray for intervention and outcomes.[28-58,63-71] These investigations clearly show that pre-post nasium x-ray alignment can be improved with

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chiropractic interventions and that a variety of patient disorders improve/respond to this type of intervention. Only a few will be detailed.

Aldis and Hill[28] reviewed 140 cases treated with the Pettibon upper cervical methods. Atlas laterality (UA) and lower angle (LA) on the Nasium and axial rotation on the vertex were compared pre and post-adjustment. Statistically significant differences were noted with an average reduction of the three subluxation measures on the post radiographs.

Grostic and DeBoer[29] retrospectively examined 523 cases treated and analyzed with the Grostic technique. Pre and post UA and axial rotation subluxations on the Nasium and Vertex views were used as outcome measures. Initial radiographic measures were UA = 2.63° and atlas rotation = 2.75°. On the post-treatment radiographs an approximate reduction of 1.23° in the UA and 1.32° for the axial rotation subluxations was found.

Anderson[30] retrospectively reported on the pre and post upper cervical alignment of 301 patients treated with the Grostic technique. The pre-post nasium view showed a consistent average reduction of atlas laterality.

Peet, Garde, and Markos[63-71] have presented several case reports where the Chiropractic Biophysics technique Nasium analysis and adjustments were used in the treatment of pediatric patients with a variety of health related conditions. These reports demonstrate consistent reduction of upper cervical subluxations using the Nasium and x-ray and consequent improvement in health status of pediatric patients.

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3. APOM Radiographic View

RECOMMENDATION

The APOM Radiographic view is indicated for the routine quantitative assessment of the biomechanical components of vertebral subluxation. This radiographic view has reliability, validity and clinical outcomes data that evidence its clinical utility in clinical chiropractic practice. When using this radiographic view a baseline value of the biomechanical component of spinal subluxation should be determined prior to the initiation of chiropractic treatment intervention. In this manner, response to care can be determined.

Supporting Evidence: Clinical Levels IV and V, Population Studies Class 4, Reliability Studies Class 2, Biomechanics, and Validity.

PCCRP Evidence Grade: Clinical Studies = C, D.

Introduction

According to Hart[8] a medical doctor in Germany appears to have been the first to describe the procedure for obtaining the anterior to posterior open mouth (APOM) radiographic view. By the 1930s, chiropractors were including the occiput in the view's analysis, along with the traditional C1 and C2 assessment.[8]

The AP Open Mouth (APOM) cervical radiographic view is an integral part of the Davis Series, which is a set of 7 radiographs of the neck recommended after a whiplash injury.[7] See **Figure 1**.

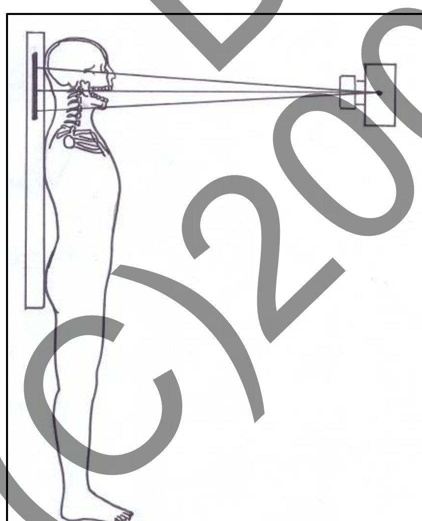

Figure 1. The APOM upper cervical view. For the APOM view, the patient stands with head against the grid cabinet and mouth open. The tube is horizontal to the uvula and collimation is below the eyes.

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This view requires no special equipment and positioning, with the exception of asking the subject to open his/her mouth. In a section on a routine spine evaluation, Hildebrandt[2] did not discuss this APOM view.

Johnson and Lucas[3] have reviewed 1033 nontraumatic cases and found only a small percentage had abnormalities visible on the APOM. They agreed with the APOM's use in trauma cases, but suggested that the APOM be only sparingly used in nontraumatic cases. The non-trauma cases where the APOM is recommended by them are:

1. congenital anomalies
2. history of previous trauma
3. osteoarthritis
4. rheumatoid arthritis
5. Down syndrome
6. ankylosing spondylitis.

Reliability of Line Drawing Methodology

Only one investigation detailing the reliability of line drawing measures of subluxation on the APOM could be found. In a 1996 case report,[10] three examiners analyzed three separate anterior-posterior open mouth radiographs taken in 1985, 1986, and 1989 of the same patient. Measurements included laterality of the atlas and axis, side of acute atlas angle, and extent of vertebral rotation. No significant examiner differences were reported.[10]

Although only 1 small investigation could be located on measurement reliability of the APOM, it is the consensus of the PCCRP panel that measurements on this view would be reliable. This PCCRP consensus opinion is due to the facts that: 1) x-ray line drawing is simply Euclidian Geometry and 2) that all other line drawing methods for spinal subluxation measurement have been found to be reliable (See Section VIII).

Reliability of Patient Positioning

Although no investigations could be located on positioning reliability of the APOM, it is the consensus of the PCCRP panel that patient positioning for this view would be reliable. This PCCRP consensus opinion is due to the facts that: 1) that posture has been shown to be repeatable[15] and 2) that in the previous Section IX, the majority of studies showed reliability of positioning for other radiographic views.

There is, however, an optimal positioning procedure to improve visualization of the upper cervical spine on the APOM radiographic view. Wylie[9] investigated two different patient positions for obtaining the APOM radiograph; where 30 subjects were x-rayed for each view. The 1st method was the standard approach where the upper incisors are and the mastoid process is placed in a horizontal position relative to the reference floor level. The 2nd method utilized a slight head extension with the central ray bisecting the atlas (just inferior to the mastoid process); equal distance between the upper and lower teeth relative to the central ray is needed. The 2nd method was found to provide clinically superior visualization of upper cervical structures.[9]

Diagnostic Capabilities

Diagnostic usability is inherent on each radiographic view for the object on the central ray. In the case for the APOM view, the objects on the central ray are the two upper cervical vertebrae, C1 and C2. This view, as an integral part of a Davis Series in whiplash, is used to determine the possible dislocations, possible fractures, and soft tissue injuries to the C1 and C2 area. However, besides just the Davis Series, the lateral cervical, AP cervical view, and the APOM have been recommended in all cases of cervical spine trauma.[1,5,6]

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Some have suggested that the APOM view should be included in all cervical spine radiographic series regardless of indication of trauma or pain.[4,5] Furthermore, some chiropractic clinicians and techniques include the biomechanical assessment of the atlanto-occipital and atlanto-axial articulations by using the AP open-mouth radiograph procedure as part of their treatment decision making process.[8,12]

Validity

Besides the multitude of fractures, dislocations, and soft tissue injuries reported in the literature for the APOM view during a Davis series, Johnson and Lucas reported on 10 non-trauma cases, with rheumatoid arthritis, metastatic carcinoma, degenerative joint disease, Down syndrome, erosion of the odontoid, and atlanto-axis instability.[3]

Sickesz and VanDerSchaar[12] described their experience dealing with 'several thousand whiplash cases over 3 decades by reporting the 'typical presentation' of subluxation displacements of the upper cervical spine, C0-C3, on the APOM radiograph. They described y-axis and z-axis (gravitational axis and lateral flexion) displacements as being very common after whiplash.

An investigation by Yi-Kai et al[11] questioned the validity of APOM for upper cervical subluxation measurements.[11] Yi-Kai et al[11] concluded that APOM upper cervical alignments are not different for 87 neck pain patients compared to 21 controls. The only measurement recorded was the Odontoid to lateral mass interspace distance on the left versus right side; no angular measures were recorded nor was the 'overhang' of C1-C2 joint on the outside (these measures are more clinically and biomechanically relevant). Problematically, Yi-Kai et al[11] lumped acute (1 day duration) and chronic (4 years duration) subjects together and subjects were a 'conglomeration' of conditions ranging from neck pain and headaches to shoulder pain and vertigo. Therefore, the study by Yi-Kai et al[11] has serious methodological flaws.

<u>Biomechanical Validity</u>:

For biomechanical validity, the clinician compares the spinal coupled motions on the APOM radiograph to the published results of "main motion coupled motion" performed on head postural movements. If the usual coupled motion patterns on APOM cervical radiographs are not present for a particular head posture, the clinician is alerted to the fact that either anomalies or spinal injuries are present.

Several main motion/coupled motion investigations have been reported for head movements of lateral bending and axial rotation and their consequent APOM radiographic patterns.[13,14]

Outcome Investigations

Only two investigations reporting on the pre and post subluxation alignment of the upper cervical spine on the APOM radiographic view could be located.[10,12] However, several upper cervical techniques utlize this radiographic view in their initial decision making process although post-treatment APOM radiographs may not be obtained.[16]

<u>Level I Studies</u>: No Level I studies could be located.

<u>Level II Studies</u>: No Level II studies could be located.

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Level III Studies: No Level III studies could be located.

Level IV Studies:

In a case report with a 4 year follow up, Hart[10] reported non-statistically but clinically significant improvements in the upper cervical alignment of initial and follow-up APOM radiographs. Hart[10] noted that the patient's condition improved although the 'overall pattern' of the patient's subluxation on x-ray remained the same.

In a retrospective case series, Sickesz and VanDerSchaar[12] reported on 40 randomly selected patients with chronic whiplash associated disorders. The APOM subluxation displacements of C1 and C2 were utilized to help determine intervention. Compared to initial presentation, the 3-month follow-up examination showed complete resolution in the majority of subjects' complaints.

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4. Blair Protracto Views

RECOMMENDATION

The Blair Protracto Radiographic view is indicated for the routine quantitative assessment of the biomechanical components of vertebral subluxation. This radiographic view has reliability, validity, and clinical outcomes data that evidence its clinical utility in clinical chiropractic practice. When using this radiographic view a baseline value of the biomechanical component of spinal subluxation should be determined prior to the initiation of chiropractic treatment intervention. In this manner, response to care can be determined.

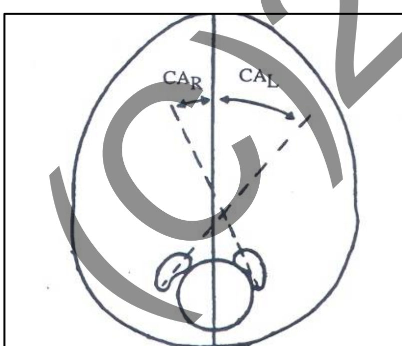
Supporting Evidence: Clinical Levels I, IV and V, Biomechanics, Reliability Studies Class 2, and Validity.

PCCRP Evidence Grade: Clinical Studies = B, C, D.

Introduction

The Blair Condyle Radiographic views were originated by Blair.[1-4] The term Condyle Protracted view was used by Blair. He originated the idea that the head may translate-subluxate obliquely on the atlas along the long axis of one lateral mass. If this occurred, the opposite side skull condyle-lateral mass articulation will have a laterolisthesis type displacement. A Base Posterior radiographic view is needed before the Blair "Convergence Angles" can be determined. (Figure 1)

This view requires a little more work in equipment and positioning time compared to any other AP cervical view. Blair devised a special head clamp system in which the head clamps could be rotated away from the grid cabinet. He did this in the amount exactly equal to each Convergence angle. In actuality, the head was rotated by the amount of the Convergence angle, and thus, was in a slight oblique position relative to a true AP cervical or nasium. The central ray was therefore directed through the maxillary sinus opposite the condyle-lateral mass articulation to be studied. (Figure 2)



Blair's Convergence Angles of the Condyles

Figure 1. The Blair Condyle Convergence Angles were measured on a Base Posterior radiographic view. These angles determined the amount of head rotation for taking the Blair Condyle Radiographic views, which are in effect slight obliques.

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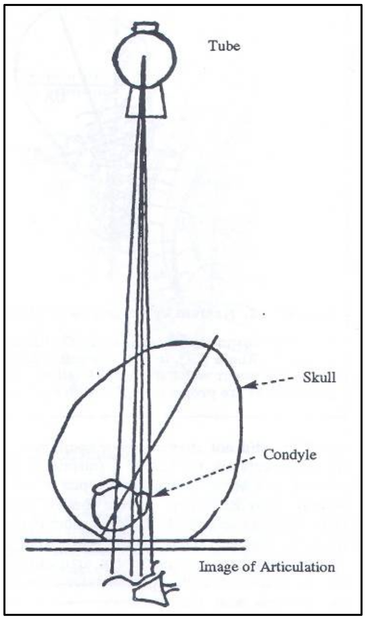

Figure 2. Blair Condyle Protracted View. The head is rotated by the amount of the convergence angle to the side of the condyle-lateral mass articulation to be observed. If the joint edges appear normal, then the head was assumed to have translated either forward or backward in the plane of this joint. If the condyle appeared to be medially displaced from the lateral mass, then the head translated obliquely posterior in the axis of the opposite side joint. If the condyle appeared displaced laterally compared to the lateral mass on this view, then the head translated obliquely forward in the long axis of the opposite side joint.

Other Chiropractic Techniques, such as BJ Palmer's HIO, use measurements on the Base Posterior view to determine the care of a patient. However, the Condyle Protracted Views are specific to Blair Technique. Without this view, the Blair Practitioner cannot determine the proper care of his/her patient. Information from these views is used to position the patient for adjusting, to determine where the adjustive force is applied, and what the line of correction (vector) will be. The adjustment can be manual or instrument assisted.

Reliability

Addington et al[5,6] found 80-90% agreement for the direction of subluxation between examiners for upper cervical subluxation on the Blair technique views.

Reliability of Patient Positioning

Although no investigations could be located on positioning reliability of the Blair Protracto views, it is the consensus of the PCCRP panel that patient positioning for this view would be reliable. This PCCRP consensus opinion is due to the facts that: 1) that posture has been shown to be repeatable[15] and 2) that in the previous Section IX, the majority of studies showed reliability of positioning for other radiographic views.

Diagnostic Capabilities

Diagnostic usability is inherent on each radiographic view for the object on the central ray. Besides being the only view on which the condyle-atlas articulation one each side of the head can be precisely visualized, these views provides the best visualization of maxillary sinuses.

Validity

Biomechanical Validity:

For biomechanical validity, the clinician compares the spinal coupled motions on the Blair Protracto radiograph to the published results of "main motion coupled motion" performed on head postural movements. If the usual coupled motion patterns on the Blair radiographs are

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not present for a particular head posture, the clinician is alerted to the fact that either anomalies or spinal injuries are present.

Several main motion/coupled motion investigations have been reported for head movements of lateral bending and axial rotation and their consequent condyle atlas displacement patterns.[7,8]

Outcome Investigations

Level I Studies:

Brown et al[9] randomly assigned twenty subjects to either a Blair or a Grostic technique radiographic analysis and intervention to assess possible differences in initial atlas laterality, post-treatment correction, and patient improvements. Subjects completed a Rand SF-36 survey before and at the end of 4 weeks of care, to assess general health and quality of life. In 11/20 subjects (55%), atlas laterality was the same between the two techniques (kappa=0.08). Statistically significant improvements were observed between SF-36 scores pre and post care. No significant differences in change from baseline scores were observed between the two techniques.

Level II Studies: No Level II Studies could be located.

Level III Studies: No Level III Studies could be located.

Level IV Studies:

There are several case studies, case series, and cohorts without controls in the chiropractic literature utilizing the Blair Protracto x-ray views for intervention and outcomes.[10-14] These investigations clearly show that occipital-atlas alignment on the Blair x-ray views can be improved, can alter chiropractic intervention techniques, and that a variety of patient disorders improve/respond to this type of analysis and intervention.

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5. Vertex View

RECOMMENDATION

The Vertex Radiographic view is indicated for the routine quantitative assessment of the biomechanical components of vertebral subluxation. This radiographic view has reliability, validity, and clinical outcomes data that evidence its clinical utility in clinical chiropractic practice. When using this radiographic view a baseline value of the biomechanical component of spinal subluxation should be determined prior to the initiation of chiropractic treatment intervention. In this manner, response to care can be determined.

Supporting Evidence: Clinical Levels I, III, IV, V, Biomechanics, Reliability Studies Class 2, and Validity.

PCCRP Evidence Grade: Clinical Studies = B, C, D.

Introduction

The Vertex upper cervical radiographic view was originated by A.A. Wernsing, DC[1] in 1930 and later adapted in the Grostic Technique.[2] Although Wernsing obtained this view without the use of head clamps, Grostic recommended their use. This view is taken sitting on a specifically designed positioning chair, which can be mechanically moved in various directions by the x-ray technician. (**Figure 1**).

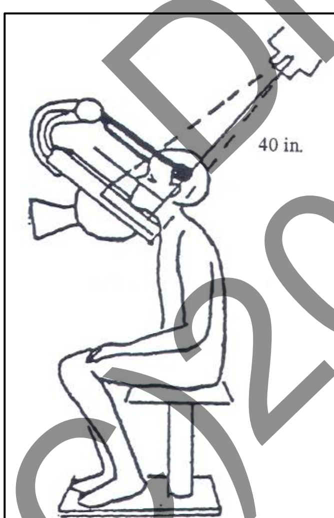

Figure 1. The Vertex upper cervical view. For the Vertex view, the patient sits on a movable positioning chair and puts the chin on the midline of grid cabinet. Head clamps are used to take out rotation & tilt. The tube is positioned above the subject's head and perpendicular to the APL.

This view requires some special equipment and positioning. The specialized equipment includes a tilting grid cabinet, a tiltable x-ray tube, an x-ray frame that will allow the tube and grid cabinet distance to be less than 40 inches, and precision head clamps.

A lateral cervical x-ray must be obtained of a subject in order to determine the tilt and height of the x-ray tube compared to the subject's facial features. This tilt and tube height is derived from the atlas plane line on the lateral cervical view. On the lateral view, a line through the atlas is compared to horizontal and given either an "S-Line" designation (1 SL = 10º) or is just measured in degrees. The patient is positioned facing the grid cabinet, which is placed on

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angle. (See Figure 1) Using the orientation of the APL in space, the tube is positioned perpendicular to this line.

Measurements are made on the Vertex view in degrees (Figure 2). The skull is bisected using the edges of the parietal bones or by a line following the mid-floor structures of the cranium. Depending on the Technique system, a line is drawn through the atlas (APL in Vertex view).[1-12] Wernsing[1] and Grostic[2] utilized the foramens (intertransversariae) for the vertebral arteries within the transverse processes of C1. These two lines create an Angle of rotation of the head relative to C1 about vertical gravity.

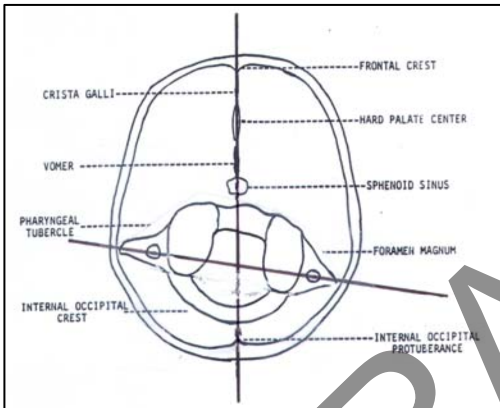

Figure 2. The Vertex view is obtained by placing the tube overhead perpendicular to the atlas plane line (APL) determined in the lateral view (Figure1). Measurements on this view are to determine any axial rotation of the skull-atlas joint. The skull is bisected (Center skull line) and the APL is drawn through the vertebral artery holes in the C1 transverse processes. In this example, the atlas is rotated anterior on the left side.

Many Upper Cervical Chiropractic Techniques use measurements on the Vertex view to determine the care of a patient. This determination includes how the patient is positioned for adjusting, where the adjustive force is applied, and what the line of correction (vector) will be. The adjustment can be manual or instrument assisted. Furthermore, these techniques require that a post treatment Vertex x-ray be obtained to verify a successful intervention; i.e., a reduction in the subluxation misalignment of the atlas.

Reliability of Line Drawing Methodology

In a 1992 review of the literature on upper cervical x-ray marking studies, Owens concluded that studies have reported inter- and intra-examiner reliability are sufficient to measure rotational displacements of C1 to within ± 1º on the Vertex x-ray view.[13]

Reliability of Patient Positioning

Although no investigations could be located on positioning reliability of the Vertex view, it is the consensus of the PCCRP panel that patient positioning for this view would be reliable. This PCCRP consensus opinion is due to the facts that: 1) that posture has been shown to be repeatable[14] and 2) that in the previous Section IX, the majority of studies showed reliability of positioning for other radiographic views.

Diagnostic Capabilities

Diagnostic usability is inherent on each radiographic view for the object on the central ray. Besides being the only view on which the atlas articulation with the head in axial rotation can be precisely measured, the Vertex view provides the best visualization of C1 for Jefferson fractures. Additionally, the Vertex view is quite similar in projection and positioning to the

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Water's Projection medical view. For the Water's view, the patient faces the grid cabinet, extends his/her head with no rotation or tilt and the view is taken at 37° caudal. There are a multitude of boney objects visualized for normal anatomy on this view.[15]

<u>Validity</u>

The vertex view was an integral part of several upper cervical techniques including Wernsing's Atlas Specific, Grostic, NUCCA, Sweat's Atlas Orthogonal, Pettibon, Don Jones' Life Cervical, Orthospinology, and Harrison's CBP Technique. There are numerous case studies from these techniques, but also this radiographic view is featured in a recent text by Erikson.[3] Since the Base Posterior view and the Vertex view are taken along the same projection line through the head and have similar measurements for atlas rotation compared to the skull,[16] validity or efficacy of one view is analogous for the other view.

<u>Biomechanical Validity</u>:

For biomechanical validity, the clinician compares the spinal coupled motion directions and magnitudes on the Vertex radiograph to the published results of "main motion coupled motion" performed on head postural movements. If the usual coupled motion patterns on the Vertex radiographs are not present for a particular head posture, the clinician is alerted to the fact that either anomalies or spinal injuries are present.

Several main motion/coupled motion investigations have been reported for head movements of lateral bending and axial rotation and their consequent condyle atlas displacement pattern and magnitude for the rotation of the skull and atlas about gravity.[17-20]

<u>Outcome Investigations</u>

The C1 rotation under the skull has been used at the Institute for Orthomanual Therapy in The Hague, The Netherlands and at the International Biomedical Center in Leende, The Netherlands.[21] Several outcome investigations have been reported where the Vertex view was an integral part of the treatment decision making process. These investigations clearly show that occipital-atlas alignment on the Vertex x-ray view can be improved, can alter chiropractic intervention techniques, and that a variety of patient disorders improve/respond to this type of analysis and intervention.[7,21-39]

<u>Level I Studies</u>:

At least 2 randomized trials were found where the Vertex radiographic view was utilized to direct treatment interventions.[22-23] Only the most recent of these will be discussed.

In a randomized trial, Khorshid et al[22] assigned 14 autistic children to a full spine adjustment technique or the Atlas Orthogonal upper cervical technique where the Vertex radiograph was one of the x-ray views used to determine the subluxation and adjustment. All subjects were evaluated using the Autism Treatment Evaluation Checklist (ATEC). Treatment duration was 3-5 months with monthly assessments including pre and post x-ray and leg length analysis. Improvement of ATEC scores was seen in 6/7 children under upper cervical care and in 5/6 under full spine adjustment. Average total ATEC improvement in the upper cervical group was 32%, while only 8.3% in the full spine group. Two autistic children under the upper cervical adjustment protocol no longer met the criteria to be considered autistic following the interventions. Post adjustment Vertex x-rays showed reduction of the structural subluxation of the skull relative to the atlas.

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Level II Studies: No Level II studies could be located.

Level III Studies:

In 1999, Hoiriis et al[24] used a practice based research design to document the effects that upper cervical adjusting has on the Global Well Being Scale (GWBS) and the Rand SF-36 outcome measures scale in a patient population with predominant musculoskeletal complaints. Compared to initial measures, the 4-week outcomes showed statistically significant improvements in 6/8 of the SF-36 subscales. Whereas, compared to initial values, when the patient reached maximum chiropractic improvement statistically significant improvements in 7/8 of the SF-36 subscales were seen.

Level IV Studies:

There are a large number of case studies, case series, and cohorts without controls in the chiropractic literature utilizing the Vertex radiographic view for intervention and outcomes.[7,21,25-39] These investigations clearly show that pre-post Vertex x-ray alignment can be improved with chiropractic interventions and that a variety of patient disorders improve/respond to this type of analysis and intervention. Only a few will be detailed.

Grostic and DeBoer[7] retrospectively examined 523 cases treated and analyzed with the Grostic technique. Pre and post UA (upper angle) and axial rotation subluxations on the Nasium and Vertex views were used as outcome measures. Initial radiographic measures were UA = 2.63° and atlas rotation = 2.75°. On the post-treatment radiographs an approximate reduction of 1.23° in the UA and 1.32° for the axial rotation subluxations was found.

In 2004, Sickesz and VanDerSchaar[21] reported on their experiences with several thousand cases of whiplash injury, where the Vertex radiographic measurement has been used to determine C1 rotation under the skull. They demonstrate adjustments to correct this "luxation" of C1 and report on 40 retrospective randomly selected cases.

Aldis and Hill[25] reviewed 140 cases treated with the Pettibon upper cervical methods. Atlas laterality (UA) and lower angle (LA) on the Nasium and axial rotation on the vertex were compared pre and post-adjustment. Statistically significant differences were noted with an average reduction of the three subluxation measures on the post radiographs.

Anderson[26] retrospectively reported on the pre and post upper cervical alignment of 301 patients treated with the Grostic technique. The Vertex view identified that most patients attained a 2° average reduction in axial rotation while 15% of the subjects attained a 4° or more reduction in subluxation displacement.

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6. <u>Base Posterior Radiographic View</u>

RECOMMENDATION

The Base Posterior Radiographic view is indicated for the routine quantitative assessment of the biomechanical components of vertebral subluxation. This radiographic view has validity and clinical outcomes data that evidence its clinical utility in clinical chiropractic practice. When using this radiographic view a baseline value of the biomechanical component of spinal subluxation should be determined prior to the initiation of chiropractic treatment intervention. In this manner, response to care can be determined.

<u>Supporting Evidence</u>: Clinical Levels I, IV, V, Biomechanics, and Validity.

<u>PCCRP Evidence Grade</u>: **Clinical Studies = B, C, D.**

Introduction

The Base Posterior upper cervical radiographic view was used in HIO since the early 1900's.[1] This view is also an integral part of the Blair Technique.[2] This view is taken sitting on a specifically designed positioning chair, which can be mechanically moved in various directions by the x-ray technician. (**Figure 1**) The Vertex view and Base Posterior view have similar goals and measurements.

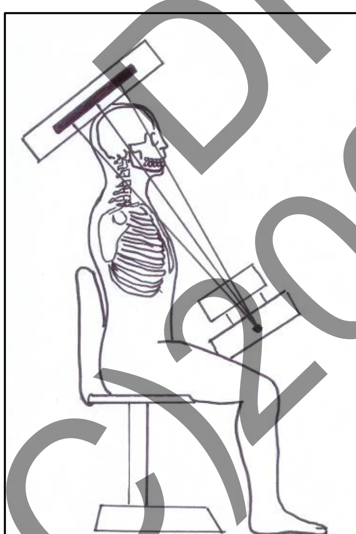

Figure 1. The Base Posterior upper cervical view. For the Base Posterior view, the patient sits on a movable positioning chair. The grid cabinet is positioned overhead and the tube is positioned between the knees. The head is positioned to take out rotation & tilt.

This view requires some special equipment and positioning. The specialized equipment includes a tilting grid cabinet, a tiltable x-ray tube, an x-ray frame that will allow the tube and grid cabinet distance to be less than 40 inches. The tube and tube stand must be movable enough to allow the tube to be positioned between the patient's knees.

A lateral cervical x-ray must be obtained of a subject in order to determine the tilt and height of the x-ray tube compared to the subject's facial features. This tilt and tube height is derived from the atlas plane line on the lateral cervical view. On the lateral view, a line through the atlas is compared to horizontal and given either an "S-Line" designation (1 SL = 10º) or is

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just measured in degrees. The patient is positioned sitting with the grid cabinet overhead, which is placed on angle. (see Figure 1) Using the orientation of the APL in space, the tube is positioned perpendicular to this line.

Measurements are made on the Base Posterior view in degrees (see Figure 2). The skull is bisected using the edges of the parietal bones or by a line following the mid-floor structures of the cranium. Depending on the Technique system, a line is drawn through the atlas (APL in Base Posterior view). The mid-foramen for the vertebral arteries is often used as the two points to create an atlas plane line (APL). These two lines (bisected skull floor structures and APL) create an Angle of rotation of the head relative to C1 about vertical gravity.

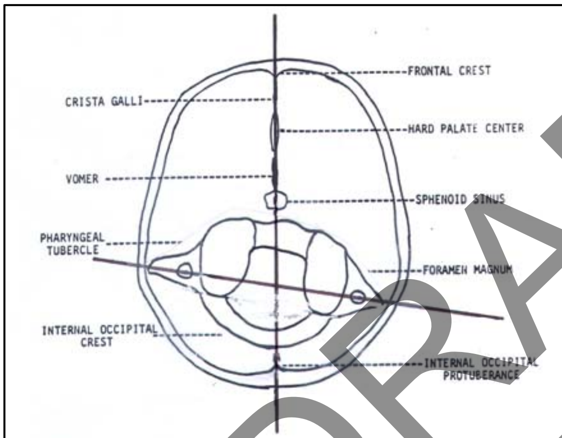

Figure 2. The Base Posterior view is obtained on the same angle as the Vertex view except the tube and grid cabinet are reversed. (Figure1). The major difference between the two views is that the atlas will appear larger (magnified) in the Base Posterior view. Measurements on this view are to determine any axial rotation of the skull-atlas joint. The skull is bisected (Center skull line) and the APL is drawn through the vertebral artery holes in the C1 transverse processes. In this example, C1 is rotated anterior on the left.

Many Upper Cervical Chiropractic Techniques use measurements on the Base Posterior view to determine the care of a patient. This determination includes how the patient is positioned for adjusting, where the adjustive force is applied, and what the line of correction (vector) will be. The adjustment can be manual or instrument assisted. Furthermore, these techniques require that a post treatment Base Posterior x-ray be obtained to verify a successful intervention; i.e., a reduction in the subluxation misalignment of the atlas.

Reliability of Line Drawing Methodology

To our knowledge the Base Posterior view has never been subjected to a reliability study. However, it is the consensus of the PCCRP panel that measurements on the Base Posterior radiographic view would be reliable. This PCCRP consensus opinion is due to the facts that: 1) x-ray line drawing is simply Euclidian Geometry and 2) that all other line drawing methods for spinal subluxation measurement have been found to be reliable (See Section VIII).

Reliability of Patient Positioning

No investigations could be located on positioning reliability of the Base Posterior radiographic view. However, it is the consensus of the PCCRP panel that patient positioning for the Base Posterior radiographic view would be reliable. This PCCRP consensus opinion is due to the facts that: 1) posture has been shown to be repeatable[3] and 2) that in the previous Section IX, the majority of studies showed reliability of positioning for similar radiographic views.

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Diagnostic Capabilities

Diagnostic usability is inherent on each radiographic view for the object on the central ray. Besides being one of the only views on which the atlas articulation with the head in axial rotation can be precisely measured, the Base Posterior view, like the Vertex view, provides the best visualization of C1 for Jefferson fractures. Additionally, the Base Posterior view and the Vertex view are quite similar in projection and positioning to the Water's Projection medical view. For the Water's view, the patient faces the grid cabinet, extends his/her head with no rotation or tilt and the view is taken at 37^{o} caudal. There are a multitude of boney objects visualized for normal anatomy on this view.[4]

Validity

Biomechanical Validity:

For biomechanical validity, the clinician compares the spinal coupled motion directions and magnitudes on the Base Posterior radiograph to the published results of "main motion coupled motion" performed on head postural movements. If the usual coupled motion patterns on the Base Posterior radiograph are not present for a particular head posture, the clinician is alerted to the fact that either anomalies or spinal injuries are present.

Several main motion/coupled motion investigations have been reported for head movements of lateral bending and axial rotation and their consequent condyle atlas displacement pattern and magnitude for the rotation of the skull and atlas about gravity.[5-8]

Outcome Investigations

Level I Studies:

Brown et al[9] randomly assigned twenty subjects to either a Blair or a Grostic technique radiographic analysis and intervention to assess possible differences in initial atlas laterality, post-treatment correction, and patient improvements. Radiographic examination including the Base Posterior radiographic view, was performed on each subject. Subjects completed a Rand SF-36 survey before and at the end of 4 weeks of care, to assess general health and quality of life. In 11/20 subjects (55%), atlas laterality was the same between the two techniques (kappa=0.08). Statistically significant improvements were observed between SF-36 scores pre and post care. No significant differences in change from baseline scores were observed between the two techniques.

Level II Studies: No Level II studies could be located.

Level III Studies: No Level III studies could be located.

Level IV Studies:

The Base Posterior view was an integral part of HIO technique originated and used by BJ Palmer. There are numerous case studies in Palmer's texts that can be obtained from the Palmer Chiropractic College Library.[1]

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In 2004, Sickesz and VanDerSchaar[10] reported on their experiences with several thousand cases of whiplash injury, where this x-ray view has been use to determine C1 rotation under the skull. Interestingly, they give credit to Palmer for originating the "Palmer basal-posterior projection". They demonstrate adjustments to correct this "luxation" of C1 and report on a sample of 40 retrospective, randomly selected cases.

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7. <u>Lateral Cervical Radiographic View</u>

RECOMMENDATION

The Lateral Cervical Radiographic view is indicated for the routine quantitative assessment of the biomechanical components of vertebral subluxation. This radiographic view has reliability, validity, and clinical outcomes data that evidence its clinical utility in clinical chiropractic practice. When using this radiographic view a baseline value of the biomechanical component of spinal subluxation should be determined prior to the initiation of chiropractic treatment intervention. In this manner, response to care can be determined.

<u>Supporting Evidence</u>: Clinical Levels I-V, Population Studies Class 1-4, Biomechanics, Reliability Studies 1 and 2, and Validity.

<u>PCCRP Evidence Grade</u>: Clinical Studies = B, C, D.

Introduction

In radiography of the cervical spine, the first view to be obtained is generally the lateral cervical view. Care should be taken to insure that several structures are visible from the sellae turcica superiorly, the hard palate anteriorly, the posterior occiput, to the lower cervical spine including T1 inferiorly. In many cases, a lateral cervical thoracic filter is needed in order to adequately visualize the lower cervical spine.

The lateral cervical is taken at the standard tube distance of 182.9 cm (72 inches) with the central ray located approximately at the C4 level, however, upper cervical doctors often align the central ray with the upper cervical spine.[11] For lateral cervical x-rays, the patient's shoulders are positioned perpendicular to the x-ray bucky. There are several methods of patient positioning procedures where some authors recommend placing the patient in an 'idealized' neutral position with the hard palate level; while others recommend the 'self balance position'.[1-15] Regardless of methodology, as discussed below, the positioning is repeatable.

Since chiropractic clinicians are interested in the alignment of the patient's spine, the self balance position may be more appropriate to ascertain the patient's unique subluxation alignment. For this self balance position, the patient is instructed to close his/her eyes, to flex and extend his/her head twice, and come to a resting neutral position. This neutral resting posture is where the patient perceives his/her head to be looking straight, forward. The eyes are then opened and the patient is instructed to look straight ahead without moving. The patient's abnormal sagittal plane posture is left as is, i.e. it is not guided towards an ideal neutral position. Figure 1 depicts the 'self balance positioning' of a patient with slight head flexion in their neutral resting posture.

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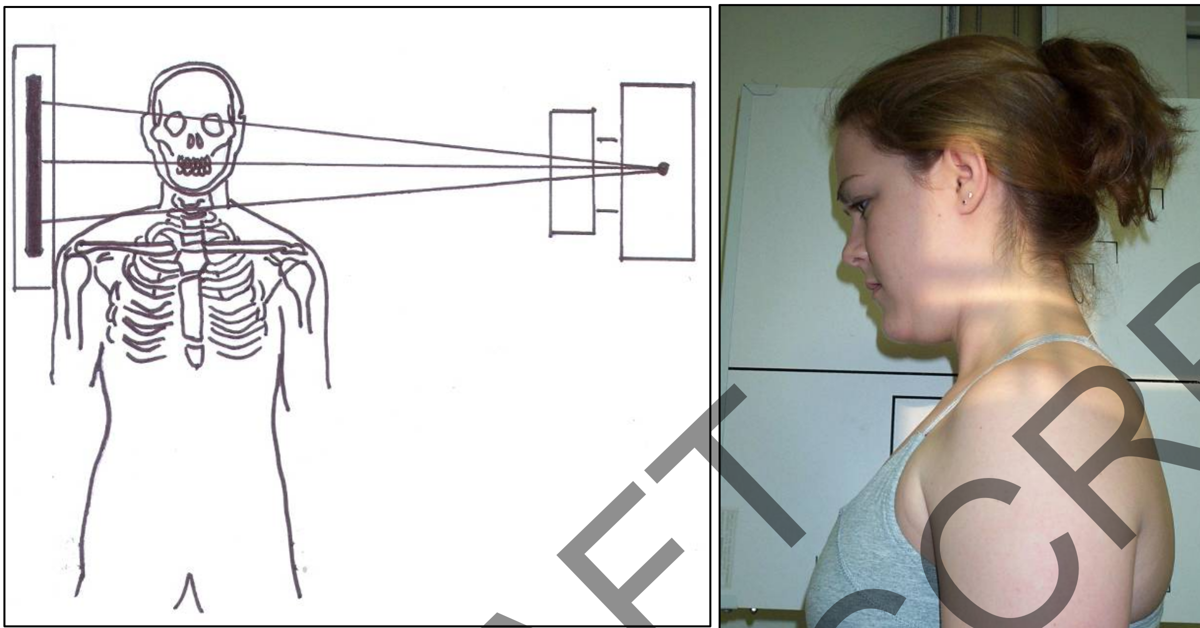


Figure 1. Self balance position. The patient is instructed to close his/her eyes, to flex and extend his/her head twice, and come to a resting neutral position. The eyes are then opened and the patient is instructed to look straight ahead without moving. The patient's abnormal sagittal plane posture is left as is. The example of head flexion is shown.

Reliability of Measurement Methods

Numerous researchers have published reliability studies on lateral cervical radiographic measurements.[11,19-27] Harrison et al[19,20] investigated reliability of the Harrison Posterior Tangent and Cobb methods for measurement of the lateral cervical radiographic alignment. (See Figure 2 and 3). They[19,20] reported that these lines have high reliability (0.70 < ICC, 0.70 < Pearson r). This method of line drawing has a very low standard error of measurement (SEM < 2.0 degrees) and small mean absolute values of observers' differences (1.0 < SEM ≤ 3.0 degrees).[20]

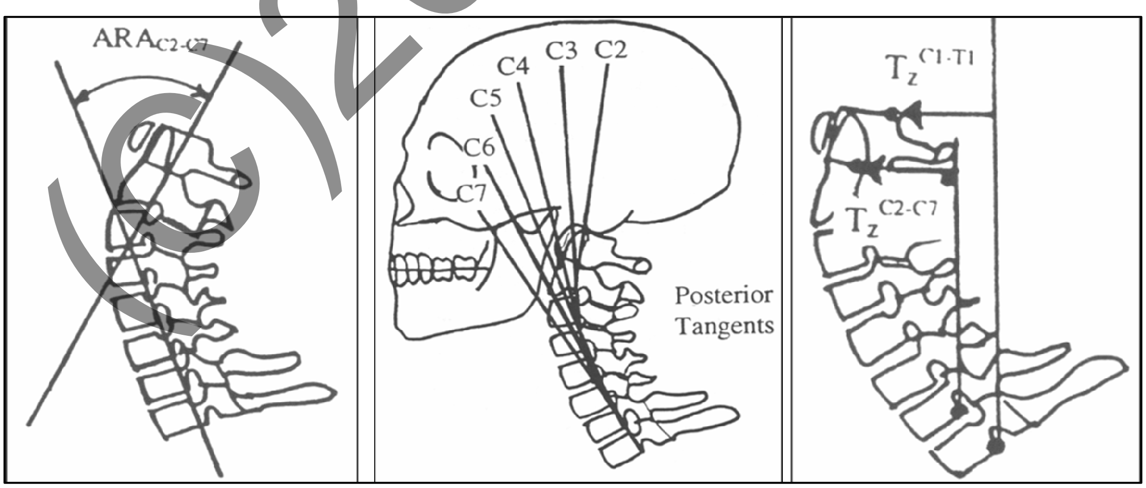
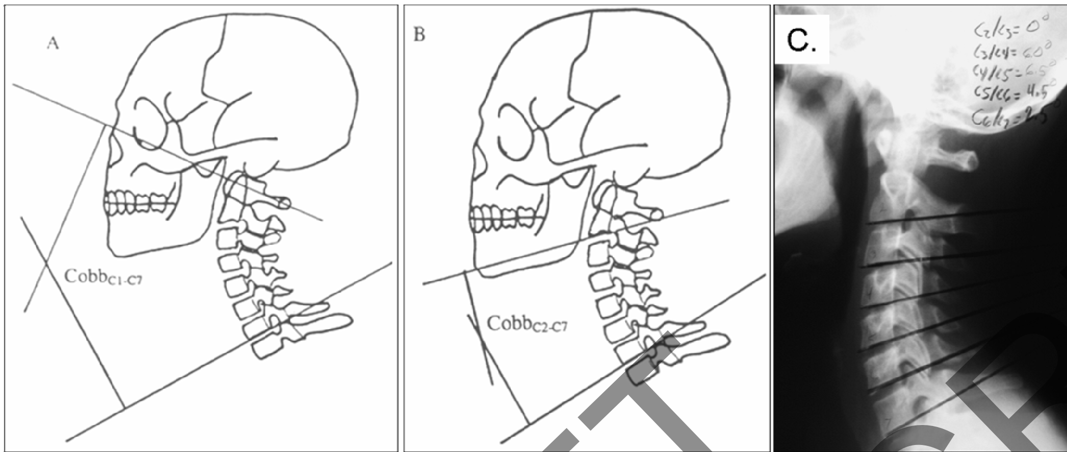


Figure 2. Harrison Posterior Tangent Method. In A, the total curve from C2-C7 for measuring the absolute rotation angle (ARA). In B, relative rotation angles (RRA's) are shown to quantify segmental angles of cervical spine curvature. In C, vertical alignment of sagittal balance is shown.



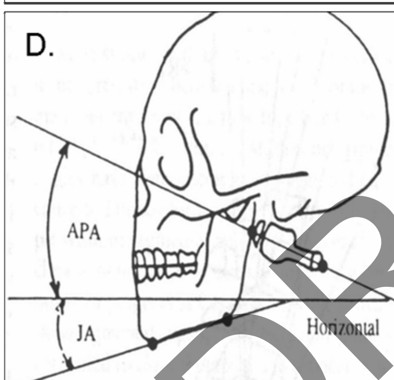


Figure 3. Cobb Method of measuring the cervical lordosis. In A, the total curve from C2-C7 is shown from measuring the total cervical lordosis. In B, the segmental Cobb method is shown for measuring segmental angulation.

Other investigators have found the 4-line Cobb angle to be reliable with a standard error of measurement (SEM) between 4°-9°.[21-23] Segmental Cobb angles have been utilized for analysis of juxta-positioned segments and these segmental Cobb or endplate angles have been found to be reliable.[20,21,23] Hermann and Geisler[24] found high intra- and inter-class correlations (ICC's) and low measurement errors (1.8° and 0.7mm) for a new computerized measurement of cervical segmental lordosis.

Shoda et al[25] investigated the reliability of several upper cervical measurement methods. They[25] found intra-observer errors for Chamberlain's line, McRae's line, and McGregor's line were 2.0º, 4.7º, and 1.5º respectively while intra-observer ICCs were 0.956, 0.835, 0.975. Inter-observer mean errors for these lines were 2.3º , 5.0º , and 1.4º respectively; while inter-observer ICC's were 0.939, 0.802, and 0.972.

Collectively these studies indicate that measurement of the lateral cervical radiographic alignment has excellent observer reliability for a variety of methodology.[11,19-27]

Repeatability of Patient Positioning

At least 15 manuscripts have been published describing the repeatability of lateral cervical and lateral skull radiographs.[1-15] For example, Hellsing et al.[1] performed a reproducibility study of cephalometric radiographs of 14 adults over a period of 8 months. Two exposures were taken in each series of each patient. The first was without the use of stabilizing ear rods, and the second was with the ear rods. A digitizer was used to measure 13 angles and 12

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lines relative to horizontal/vertical. After an average period of 8 months, no significant differences on follow-up films were found.

Foster et al.[2] performed a repeatability study of 9 subjects with follow-up radiographs performed after an interval of at least 2 weeks. The mean error for the angles measured ranged from 3.0° to 4.8°. However, the digitizing measurements revealed a method error ranging from 0.86° to 4.9°, indicating that the x-ray positioning errors were within the mean errors of the measurement method.

In a retrospective analysis, Luyk et al.[3] assessed the reproducibility of the natural head posture (NHP) with a mean of 4.3 radiographs per patient. Eighteen patients were analyzed in the NHP in a series of films taken over an average of a 3-year period. A control group comprised of 18 patients (where a cephalostat with ear rods for radiography in orthodontic planning was utilized) had at least 3 cephalostat films taken over a period of 3 years. The reproducibility varied by a mean of only 5.2° for the angle measured. Their results showed no significant differences ($p > 0.7$) between the two groups or the examiners. Similarly, Houston et al.[4] obtained initial and repeat cephalostat radiographs of 24 patients on the same day. X-ray positioning errors were found to be small and below the standard error of the measurement system.

Cook et al.[5,6] and Peng and Cook[7] performed a series of NHP repeatability radiographs with short and longitudinal follow up. In the first of their series[5], 217 children were randomly allocated to six different radiographic positioning groups. Repeat radiographs were taken at different intervals between the groups: immediate (4-10 minutes) repeat radiographs, delayed (1-2 hours) repeat radiographs, and months (3-6 months) later. In one of their groups, where a self balance position with a mirror was used on the initial and the NHP without a mirror on the repeat, significant differences were detected at $p \leq 0.01$; the maximum error was only 2.9°. In 5 of the 6 groups, no significant differences were found between the initial and repeat radiographs. In both a 5[6] and 15[7] year follow up on these subjects, similar repositioning errors were found on the repeated radiographs. Peng and Cook[7] stated, "The 15 year head posture reproducibility therefore compared well to the original repeat recordings after 5-10 minutes and the later repeats after 5 years."

Siersbaek-Nielsen and Solow[8] took initial and repeat lateral cephalometric films of 30 subjects between the ages of 6-15 years. The x-rays were taken between 1-35 days apart; where 21 were made by the same examiner and nine were taken by different examiners for the initial and repeat x-rays. All measured values showed differences of 3.4° or less and no differences were found between examiners, age groups or time interval between x-rays. They stated, "We found no significant difference between the three different operators in spite of their different education and practical experience."[8]

Sandham[9] compared repeat lateral cervical radiographs of 12 subjects with at least 1 hour between the 1st and 2nd x-ray. Six different measures of cervical spine and head position were calculated. No statistically significant differences were noted among any of the variables between the 1st and repeat lateral cervical radiograph. [9]

In the chiropractic literature, at least 4 studies have been performed on repeated lateral cervical radiographs of the same subject. Jackson et al.[11] investigated the reliability of Pettibon patient positioning procedures. Two series of radiographs of 38 patients were taken one-half to four hours apart. Jackson et al[11] demonstrated re-positioning errors of less than 1º. Harrison and colleagues[12-14] performed three separate investigations on the repeatability of lateral cervical radiographic position procedures in control group subjects with chronic neck pain. One study[12]

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used 30 subjects with repeated x-rays taken 3-months apart, the second study[13] used 24 subjects with repeat x-rays a mean of 8.1-months apart, and the third study[14] used 33 subjects with repeated x-rays taken 8.5-months apart. All 3 studies found no significant changes in global or segmental angles of lateral cervical spine curvature.[12-14]

Lastly, in the orthopedic literature, on repeated lateral cervical radiographs of 159 subjects with an average interval of 10 years, Gore[15] found no statistically significant differences in the means and standard deviations for posterior body tangent lines between C2 and C7.

Diagnostic Capabilities

If properly performed, lateral cervical spine will provide visualization of several structures, subluxation abnormalities, anomalies, and pathologies.[16-18] The vertebral bodies, odontoid process, disc spaces, articular pillars, spinous processes, and the lower half of the skull boney landmarks should all be visualized. The lateral cervical view provides the chiropractic clinician with valuable information including:

1. Total cervical lordosis,
2. Segmental cervical lordosis,
3. Breaks in Georges' line or sagittal plane translation of the posterior vertebral body and spinous lamina junction for a general stability analysis,
4. Atlas plane angle to horizontal,
5. Skull level to horizontal and upper cervical sagittal angulation,
6. General translation alignment of the skull relative to upper thorax,
7. Stages of disc, ligament & vertebral body degenerative pathologies,
8. Stage of articular process degeneration,
9. Spinal canal dimensions,
10. A number of other anomalies, fractures, and instabilities.

Validity

Multiple investigations have been published that have found correlation and predictive validity of the lateral cervical radiographic alignment to a variety of health related conditions including:

1. acute and chronic neck pain,[28-31]
2. headaches,[31-34]
3. mental health status,[120]
4. whiplash associated disorders (WAD),[35-46]
5. segmental instability for angles 10° or greater,[46,47]
6. degenerative joint disease (DJD),[27,48-59]
7. temporal mandibular joint disorders,[60]
8. range of motion and segmental motion patterns,[61-63]
9. respiration syndromes,[64-68]
10. radiculopathy,[69,70]
11. post surgical patient outcomes,[71-76] and
12. potential for soft tissue injury under impact and inertial loads.[77-81]

Oppositely, a few investigations have found that the lateral cervical alignment measurements do not correlate to and predict the findings in the above 12 categories.[82-87] However, many of these investigations have been found to be internally flawed and detailed

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reviews of these studies have been performed.[88-92] Still some chiropractic academics continue to ignore these critiques[88-92] and the majority of scientific evidence that supports analysis of the sagittal cervical spine with the lateral cervical radiographic view[27-81,120] in favor of Level V evidence (opinion).[93] For an example of this, in a July 2006 letter directed to the major political organizations in Chiropractic, Whalen[93] stated, "*Many believe the restoration of the cervical curve to be of utmost importance, demonstrated via X-ray. However, most, if not all studies on this topic, fail to show that symptoms or quality of life were dependent on the curve.*" The PCCRP panel questions if Whalen[93] actually looked into the evidence before letting personal biases dictate his position.

In contrast, it is the consensus of the PCCRP panel that the number (56 studies) and quality of investigations finding a correlation between the lateral cervical radiographic alignment and the conditions in the above 12 categories is superior to the few negative correlation studies. Thus, we conclude that the lateral cervical radiographic alignment has positive correlation and predictive validity for the above 12 categories.[27-81,120]

For thorough understanding of the PCCRP panel's position, a brief review of a few of these studies in specific categories is provided.

<u>Item #1: Neck pain</u>

Harrison et al[28] analyzed the cervical lordosis in three groups of subjects: normal subjects, acute, and chronic neck pain subjects. Each group was limited to only lordotic cervical spines and DJD and significant anterior head translation were excluded in all groups. Segmental and total curve angles were calculated and circular modeling of the path of the posterior vertebral bodies in all subjects was performed. Statistical analysis including sensitivity/specificity analysis (ROC curves) was performed. Harrison et al[28] found statistically significant differences and good sensitivity/specificity with angle and radius of curvature measurements (acute neck pain less than 30° and chronic neck pain less than 18°) between the groups.

In a separate evaluation of asymptomatic versus neck pain subjects, McAviney et al[29] found that a 20° lordosis (posterior tangents C2-C7) was a good cutoff value (sensitivity/specificity using ROC curves). The association between cervical pain and lordosis ≤ 0° was highly significant ($p<0.0001$). A lordosis in the range of 31º - 40º was found to have the least percentage of symptoms and this was suggested as a clinical goal for Chiropractic treatment.

<u>Item #2: Headaches</u>

Several studies have investigated the correlation of altered cervical curve configuration to the presence of chronic headache pain.[31-34] Nagasawa et al[31] compared 372 patients with tension headaches to 225 controls matched for age and sex. They[31] found statistically significant differences between the two groups, with patients having straightened cervical curve configurations and low set shoulders. With increasing age, the patients' cervical curve was straight more frequently.

In a survey of over 6,000 cases of chronic headache sufferers, Braaf and Rosner[32] found that "complete or segmental loss or reversal of the normal lordotic curve of the cervical spine is the most consistent characteristic feature and very often is the only abnormality found." In 47 subjects, suffering from tension and migraine headaches, Vernon et al[33] found a high incidence of hypolordosis, straightened, and reversed cervical curve configurations.

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Item #3: Whiplash Associated Disorders (WAD)

In two recent MRI studies by Guiliano et al[36,37] hypolordosis of the cervical spine was statistically correlated to the group with sub acute (12 weeks at least) WAD compared to a matched control group. Guiliano et al[36,37] provided detailed measurement via MRI methodology. Data from Marshall and Tuchin[38] provides evidence that patients involved in a motor vehicle accident (MVA) injury have a 10° mean reduction in cervical lordosis compared to a control group.

Taken as a whole, the literature on patient's involved in an MVA and those with WAD indicates that hypolordosis,[36,37] straightened cervical curves,[39,41] and kyphotic[35,39-42] curves are risk factors for and are statistically correlated to several conditions including premature DJD, sub acute WAD, neck pain, neurogenic thoracic outlet syndrome, WAD categories 2 and 3, and generalized poor long-term outcomes.[35,37-46]

Item #4: DJD

The available evidence from finite element models,[48] analytical engineering stress/strain models,[49-52] longitudinal surgical outcome studies on matched patients with and without abnormal curves and a variety of cervical spine disorders,[51-56] non-surgical longitudinal studies,[40] cross-sectional population studies,[27,57,58] and animal models[59] all indicate that straightened, S-curves, and kyphotic cervical curves predict and/or statistically correlate to the development and/or existence of DJD. In other words, a broad scope (not just one type of evidence) of research data points to the result that abnormal curves cause and correlate to DJD.[27,48-59]

Outcome Investigations

Several outcome investigations have been performed using a variety of chiropractic procedures aimed at restoration of the cervical lordosis in a variety of patient pain and health disorders.[12-14,94-119] In at least 2 investigations no improvement in cervical lordosis has been found following chiropractic adjustment procedures.[94,95] However, 3 clinical control trials adding the chiropractic procedure of extension traction to treatment methods has shown consistent increases in cervical lordosis in treated patients versus control groups.[12-14.] Additionally, a small randomized trial on Autistic children comparing upper cervical technique to full spine technique has shown improved lordosis as a result of upper cervical adjustments dictated by radiography.[96] Furthermore, many case reports, case series and cohort studies have found that several chiropractic technique procedures can improve the cervical lordosis.[97-119] Collectively, these reports indicate that patients benefit by reduced pain, improved range of motion, decreased disability levels, and increased health status following chiropractic procedures that improve the cervical lordosis to near normal values.[12-14,96-119] Examples of these investigations follow.

Level I Studies:

In a radomized trial, Khorshid et al[24] assigned 14 autistic children to a full spine adjustment technique or the Atlas Orthogonal upper cervical technique where radiography was used to determine the subluxation and adjustment. All subjects were evaluated using the Autism Treatment Evaluation Checklist (ATEC). Treatment duration was 3-5 months with monthly assessments including pre and post x-ray (Nasium, Vertex, and Lateral Cervical) and leg length analysis. Improvement of ATEC scores was seen in 6/7 children under upper cervical care and in 5/6 under full spine adjustment. Average total ATEC improvement in the upper cervical group was 32%, while only 8.3% in the full spine group. Two autistic children under the upper cervical

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adjustment protocol no longer met the criteria to be considered autistic following the interventions. Importantly, restoration of the cervical lordosis was found on post-radiography for the upper cervical treatment group. It is possible that improvement in the cervical lordosis was partly related to the better outcome of the upper cervical treatment group.

Level II Studies:

Harrison et al[13,14] presented two prospective non-randomized clinical control trials on the use of two separate cervical extension traction devices to rehabilitate the cervical lordosis in chronic neck pain patients. Extension traction was combined with traditional chiropractic treatment interventions including drop table and cervical spine manipulation. They[13,14] found a 14°-18° increase in cervical lordosis from C2-C7 (posterior tangent lines) and simultaneous reductions in chronic neck pain intensities in the treatment group compared to no change in matched control groups who self-elected to receive no care. Long-term follow-up was performed in these two trials where treatment subjects pain and cervical curve improvements were found to be stable at 1.5 year follow-up.[13,14]

Level III Studies:

Harrison et al[12] published a retrospective clinical control trial. Extension traction was combined with traditional chiropractic treatment interventions including drop table and diversified cervical adjusting. They[12-14] found a 13.2°-18° increase in cervical lordosis from C2-C7 (posterior tangent lines) in the adjusting group where extension traction was added compared to no change in the control groups.

Level IV Studies:

In a case series, Wallace et al[97] found a 6° improvement in cervical lordosis after 24 adjustments with the Pierce method. A posterior to anterior thrust was applied to the C5 vertebra using a drop table with the patient in the prone position.

A multitude of chiropractic case reports have found that different technique interventions can improve and/or restore an abnormal cervical spine curvature. For example, Alcantara et al[99-102] and Araghi et al[103,104] presented studies where, using Gonstead technique adjusting for the cervical spine, improved lordosis on the post treatment lateral cervical radiographs of patients with post surgical syndrome[99], seizures[100], myasthenia gravis[101,103], and bell's palsy[102].

Kessinger and Boneva[105] presented the results of a patient with acute WAD and cervical kyphosis following an MVA that changed towards lordosis following the Toggle recoil adjustment procedures.

Four separate case reports using Chiropractic Biophysics technique procedures to restore the cervical lordosis were found.[106-109] Bastecki et al[106] presented the resolution of attention deficit hyper-activity disorder with concomitant restoration of the cervical lordosis in a pediatric case. Ferrantelli et al[107] presented the resolution of chronic WAD and improvement of the permanent impairment rating following restoration of cervical lordosis. Haas et al[108] presented the improvement in chronic pain and impairment following restoration of the cervical lordosis in a patient suffering with syringomyelia. Colloca et al[109] reported on improvements in lateral cervical alignment along with pain and disability improvements in 3 patients with Ehlers-Danlos Syndrome.

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Coleman et al[110] presented the improvements in cervical lordosis in 13 patients with acute whiplash associated disorders (WAD) treated with activator technique methods and stretching exercises.

Three case studies that used Pettibon technique and head weighting as the main form of active rehabilitation, have been published by Morningstar et al[111-113] All of these studies showed significant improvement of the patient's anterior head carriage, cervical lordosis and cervical or thoracic pain.

In 1981, Pierce[114] provided improvements in cervical lordosis in 22 cases with pre- and post-x-ray illustrations. These improvements in lordosis were obtained with the Pierce PA drop table adjustment at C5.

Lastly, physical medicine and physical therapists have shown that conservative treatments (exercise, stretching, etc…) are able to improve a reduced cervical lordosis following a regimen of treatments.[31] The improved lateral cervical radiographic alignments are thought to be responsible a significant amount of the pain and disability improvements.[31]

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8. <u>Lateral Head Weighted/Stress View</u>

RECOMMENDATION

The Lateral Head Weighted Radiographic view is indicated for the routine quantitative assessment of the biomechanical components of vertebral subluxation. This radiographic view has validity and clinical outcomes data that evidence its clinical utility in clinical chiropractic practice. When using this radiographic view a baseline value of the biomechanical component of spinal subluxation should be determined prior to the initiation of chiropractic treatment intervention. In this manner, response to care can be determined.

<u>Supporting Evidence</u>: Clinical Levels IV-V, Reliability Studies Class 1 and 2, Population Studies Class 2, Biomechanics, and Validity.

<u>PCCRP Evidence Grade</u>: Clinical Studies = C, D.

Introduction

The Lateral Cervical Weighted Stress View was originated by Dr. Burl Pettibon in the late 1980's. The view is taken in the same matter as the standard Lateral Cervical View – standing or seated erect at 60- 72 inches with the central ray passing through the mid-cervical spine. The only difference with this view is that the patient first has additional anterior weight secured to their forehead and usually performs some form of kinetic activity (ex.: walking on treadmill) for five minutes or more before the x-ray is taken. (Figure 1).

Figure 1 AB. In A, the patient wears the head weight symmetrically on the forehead and performs a type of kinetic activity while wearing. In B, a lateral cervical head weighting stress film is exposed to determine the effect of weighting on cervical alignment.

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The head weight belt allows the user to position extra weight to their forehead. This increased head weight will induce a postural reflex (via the cervicocollic and vestibulocollic reflexes as well as the cervical mechanoreceptors) that causes a directly opposing translation of the skull on thorax to occur. A thorough literature review of the postural reflexes involved has been published by Morningstar in 2005.[1]

The specific indication for the chiropractic clinician obtaining this view is based on the following criteria:

1. The patient must have anterior head translation in relation to the thorax,
2. The patient must have an alteration of the normal cervical lordosis (See Section V).

The amount of weight that is applied to the patient's forehead is determined by placing a small amount of weight (1-2 pounds) on the patient and visualizing their sagittal head on thorax posture. If their posture improves, but not completely, additional weight is applied until maximum postural correction is achieved. The patient usually then performs some type of kinetic activity for five minutes to allow the cervical spine time for neuromuscular adaptation and a Lateral Cervical Weighted Stress View is taken, with the head weight still on, to visualize the structural change that occurred as a result of the postural correction.

In some cases, the normal posture and normal cervical lordosis is restored as a result of the head weight (Figure 2). In other cases, the normal posture and lordosis is not completely restored (Figure 3). It is important for the chiropractic clinician to know if the lordosis/posture will return with the head weight as this determines if further structural rehabilitative procedures, such as corrective traction, might need to be administered.

Figure 2AB. In A, a neutral Lateral cervical x-ray is shown with anterior head translation and loss of the cervical curve. In B, a weighted lateral stress view with 4 pounds showing correction.

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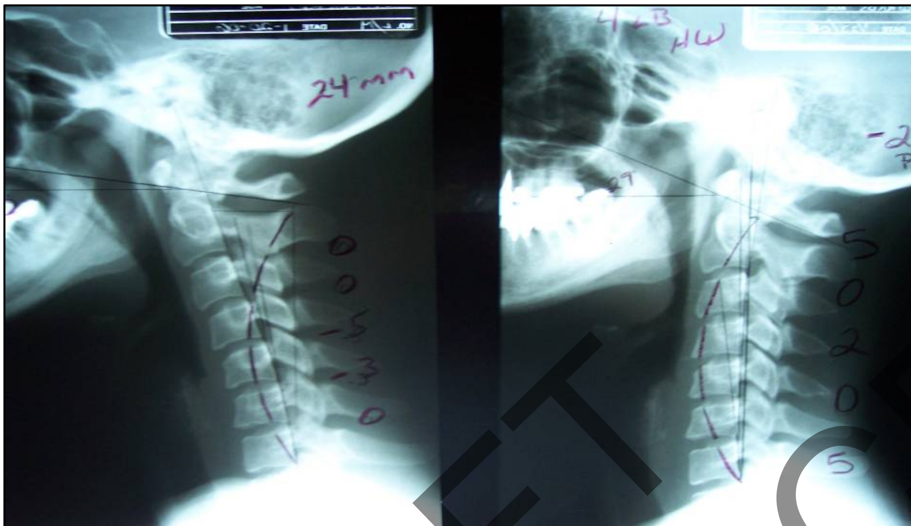

Figure 3AB. In A, a neutral lateral is shown with anterior head translation and cervical kyphosis. In B, a weighted lateral stress view with 4 pounds weight showing a lack of correction of cervical lordosis. Established, reliable measurements for cervical lordosis and anterior head translation are made on the Lateral Cervical Weighted Stress View.

Many Chiropractic structural corrective techniques (i.e.: Pettibon, Chiropractic Biophysics, etc.) utilize measurements from the Lateral Cervical Weighted Stress View to help determine the care of the patient and the amount of correction that is achievable through the patient's use of head weighting.

Reliability of Line Drawing Methodology

The measurements for segmental and total cervical lordosis and anterior head translation on the Lateral Cervical Weighted Stress View have been subjected to reliability research studies.[2-7] These measurements have excellent intra and inter examiner reliability with small standard errors of measurements. In the study by Morningstar et al,[8,9] analytical procedures for forward head posture radiographic measurement as outlined by Kapandji[10] were utilized.

Reliability of Patient Positioning

Although no investigations could be located on positioning reliability of the Lateral Head Weighted/Stress view, it is the consensus of the PCCRP panel that patient positioning for this view would be reliable. This PCCRP consensus opinion is due to the facts that: 1) that posture has been shown to be repeatable[11] and 2) that in the previous Section IX, the all studies on the Lateral Cervical X-ray view showed reliability of positioning.

Diagnostic Capabilities

Diagnostic usability is inherent as this is the only radiographic view that allows the practitioner to visualize the amount of structural and postural correction that is attainable from the patient's performance of corrective head weighting.

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Validity

Anterior head posture and deep neck flexor muscle weakness have been associated with chronic neck pain,[12-14] headaches,[15,16] thoracic outlet syndrome,[17] radicular pain,[18] TMJ and other dental dysfunctions,[19,20] and obstructive sleep apnoea.[21,22] An opposite head retraction activates the deep neck flexors and has been accurately used as a measurement of neck flexor muscle endurance.[23]

A 2005 study by McLean also showed that "*Corrected posture in standing required more muscle activity than habitual or forward head posture in the majority of cervicobrachial and jaw muscles, suggesting that a graduated approach to postural corrective exercises might be required in order to train the muscles to appropriately withstand the requirements of the task*".[24]

Biomechanical Validity:

For biomechanical validity, the clinician compares the spinal coupled motion directions and magnitudes on the Lateral Cervical Head Weighted view to the published results of "main motion coupled motion" performed on sagittal plane head postural movements. If the usual coupled motion patterns on this radiographic view are not present for a particular head posture, the clinician is alerted to the fact that either anomalies or spinal injuries are present.

Three studies detailing the kinematic coupling patterns of sagittal plane translation movement were found.[25-27] Importantly, these studies have found the same coupling patterns. Namely, that the lower cervical vertebra (C5-C7) will flex and the cervical segments C0-C4 will extend during anterior head translation and the exact opposite pattern is present with posterior head translation.[25-27]

In a 1-year follow up study on 369 subjects belonging to different occupations requiring frequent anterior displacement of the head, Choudhary[28] reported that all the subjects had radiological loss of normal lordosis of the cervical spine (straight spine) and had tender trigger points over the trapezius and other muscles of the neck. The common postural defect in all the subjects observed was the forward-head posture. Good outcomes were achieved in this group with a rehabilitation program aimed at reduction of the anterior head posture and increasing lordosis.

Morningstar et al[9] also published a 15 patient pilot study that used the Lateral Cervical Weighted Stress View to quantify a 0.83 inch average reduction in forward head posture and a 9.9° average increase of cervical lordosis immediately after five minutes of ambulatory head weighting on a treadmill and chiropractic adjustments.[9]

A study by Saunders[29] with 131 subjects, utilized the Lateral Cervical Weighted Stress View to document a 31% to 34% improvement in cervical lordosis with a reduction of forward head posture of 14-18 millimeters after five minutes of head weighting activities.[12]

All of these studies illustrate the importance of a graduated neuro-musculature rehabilitation of the normal sagittal head posture. Head weighting offers a patient friendly, easy to use, method of graduated neuro-muscular postural restoration. The Lateral Cervical Weight Stress x-ray view is the only validated method to determine what effect this will have on restoration of the cervical lordosis.

Outcome Investigations

Two investigations reporting on the pre and post subluxation alignment of the lateral cervical view where head weighting was utilized as part of the analysis and treatment were located.[8,30]

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Level I Studies: No Level I studies could be located.

Level II Studies: No Level II studies could be located.

Level III Studies: No Level III studies could be located.

Level IV Studies:

Two case studies that used head weighting as the main form of active rehabilitation, in combination with spinal manipulation, have been published by Morningstar et al.[8,30] Both of these studies showed significant improvement of the patient's anterior head carriage, cervical lordosis and cervical or thoracic pain. The Lateral Cervical Head Weighted Stress x-ray view was an integral part of treatment determination.

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9. Cervical Spine Flexion/Extension Radiographic Views

RECOMMENDATION

The Lateral Cervical Flexion/Extension Radiographic view is indicated for the quantitative assessment of the biomechanical components of vertebral subluxation. This radiographic view has reliability, validity, biomechanics and clinical outcomes data that evidence its clinical utility in clinical chiropractic practice. When using this radiographic view a baseline value of the biomechanical component of spinal subluxation should be determined prior to the initiation of chiropractic treatment intervention. In this manner, response to care can be determined.

<u>Supporting Evidence</u>: Clinical Levels III-V, Reliability Studies Class 1 and 2, Population Studies Class 2, Biomechanics, and Validity.

<u>PCCRP Evidence Grade</u>: Clinical Studies = C, D and Reliability, Biomechanics and Validity Studies = a.

Introduction

The lateral flexion and extension studies represent a means to acquire more in-depth analysis of cervical spine function and pathology. These views are typically done immediately following a neutral lateral and AP views or can be done as follow up views to aid in further analysis and patient care. These two lateral cervical views are often called the "Dynamic lateral cervical flexion-extension views" when in fact they are end range of motion static views. These views are performed sitting or standing on an 8x10 or more often a 10x12 film size.[33] (Figure 1)

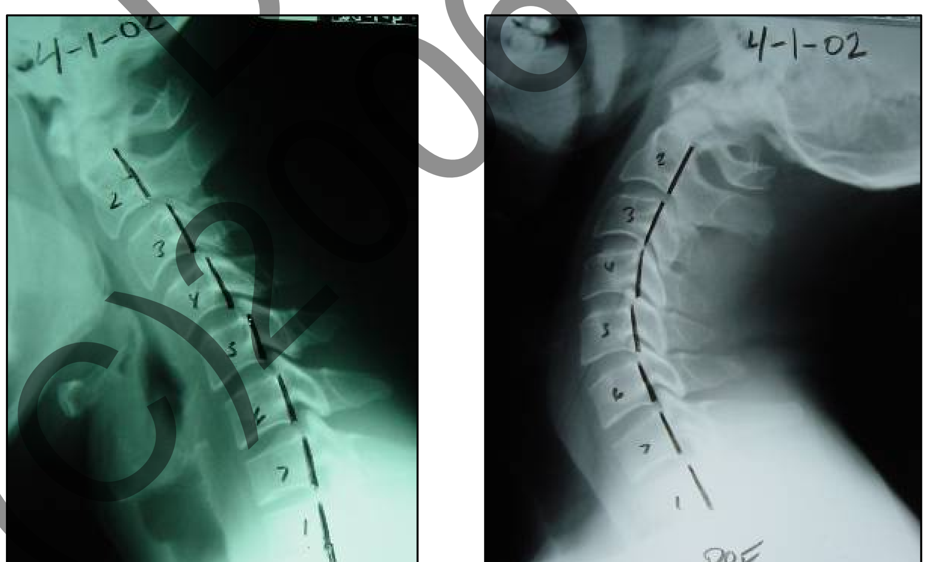

Figure 1AB. The patient must be instructed to hold his/her rib cage stationary in order to eliminate thoracic cage flexion-extension. The tube is generally at 72 inches with a 10x12 film positioned at a 90 angle to the usual cassette position. Usually the head is in maximum flexion or extension for these two radiographic views. In A, the lateral cervical flexion view is illustrated. There is a 4mm antero-listhesis of C4 on C5. In B, the cervical extension view is illustrated. There is a 3.5mm retro-listhesis of C4 on C5.

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Besides visualizing these two radiographs for obvious segmental instability, Ruth Jackson, MD was one of the first to draw some geometric lines for analysis.[12] Theses "Physiological Stress Lines" were drawn as tangents to the posterior body margins of C2 and C7.[12] Jackson thought that the location of intersection of these lines indicated the areas exposed to the greatest stress. In her classic 1957 and 1978 texts, she indicated that her "Physiological Stress Lines" should intersect at C6 in flexion and C4-C5 discs space in extension. Shortly thereafter in 1960, Zatzkin and Kveton measured the angle of intersection in Jackson stress lines to determine a normal cervical curve and compared this in whiplash cases.[34]

One of the first biomechanical studies designed to determine what ligaments are involved in segmental instability was performed by White et al in 1975.[31] Using cadaver spines, they sectioned ligaments while loading the spines in flexion or extension. With all ligaments intact, they determined values of a maximum 2.7 mm in segmental translation (x-ray magnification can make this appear as 3.5 mm) and 10.7° in angular displacement. Any translation of 4.9 mm or higher is near total failure of the cervical joints, i.e., multiple ruptured ligaments.[31]

In 1991, Dvorak et al.[3] reported on normal intervertebral rotations, translations, and locations of centers of rotation in the cervical spine in 44 healthy subjects. They added a new parameter, the ratio between translation and rotation, which may be useful for clinical diagnosis.

In 1994, Panjabi et al.[21] reported on 3-dimensional flexibility of the cervical spine in fresh C4-C7 cadaveric specimens. They reported average ranges of motion of 8.3° in flexion and 7.2° in extension. This movement decreased with an external fixator.

In 1994, Holmes et al[11] reported on cervical ranges of motion from full flexion to full extension from C2 to C7 in 78 normals and 50 Chinese cervical myelopathy subjects. Chinese subjects had similar movement patterns to Western subjects, but with slightly less movement.

In 2001, Lin et al[14] reported on normal movements in flexion and extension in 75 normal subjects. For normal flexion-extension movements, they stated that "nearly all the intervertebral differences of angular displacement were less than 7 degrees, and those of translation were less than 0.06 mm."[14]

Rotation Angle Analysis

In 1978, Penning[22] may have been the first to report on a "templating" method that became a common method of measuring segmental rotational instabilities. Using cervical flexion and extension radiographs, he would place the flexion film on top of the extension film. He would superimpose C7 on each film, then he would draw posterior tangents on C6 in the extended position and on C6 in the flexed position. He would intersect these posterior tangents on C6 to get a total angle of movement of C6 during flexion-extension relative to C7 (Figure 2).

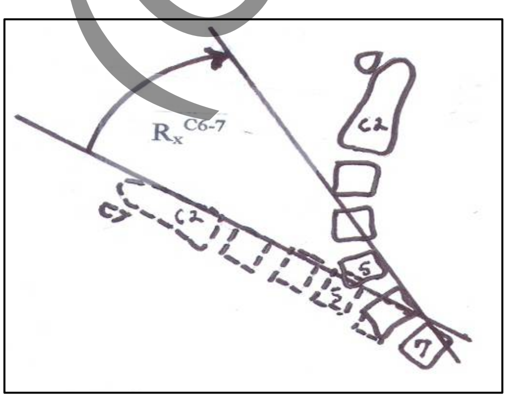

Figure 2. Penning's Flexion-Extension Templating. In 1978, Penning reported on a method to determine the maximum flexion-extension angle of movement of cervical segments C2 through C7. In this example, by superimposing C7 on both views, posterior tangents on C6 in extension and flexion provide a total angle of rotation of C6 on C7 (R_x^{C6-7}).

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Penning would, in sequence, do this "Templating" for each vertebra, i.e., C6, C5, C4, C3, and C2. Penning also attempted to measure the "axis of movement" by locating a finite rotation center (FRC) for each cervical segment compared to the segment below.[22] This analysis has often been incorrectly termed an "IAR". IAR is "infinitesimal" axis of rotation and requires a continuous function in calculus, where as FRC uses perpendiculars from lines connecting like points on a "Finite" number of vertebral positions (i.e., one flexion position/view and one extension position/view).

In 1985, Mayer et al[18] reported on a computerized method to superimpose vertebrae for Templating on flexion-extension views. They stated that time and errors are minimized by utilization of this new computer method.

In 1993, Dvorak et al.[4] reported on a computer-aided method to determine cervical instability in 64 patients, divided into 3 groups, degenerative changes, radicular signs, and whiplash trauma. Calculating segmental motion parameters, such as rotations, translations, and centers of rotation, they stated that (1) hypo-mobility was significant at C6-C7 for the degenerative and radicular groups, (2) hyper-mobility in upper and middle cervical levels for the trauma group, and (3) locations of the centers of motion were shifted in the anterior direction in the trauma group compared to healthy populations.

Reliability of Templating on Flexion-Extension Views

In 1988, 59 adults, 28 healthy adults and 31 patients, were examined by functional CT by Dvorak et al.[5] The Penning method of measurement was found to be more reliable than the Buetti-Bauml method. They[5] recommended that the flexion-extension radiographs be taken in a passive way, and not active, when comparing to normal values.

In 1989, Lind et al[15] studied the range of motion of 70 healthy subjects in maximal flexion-extension and maximal lateral flexions. Radiographs were analyzed on a digital tablet linked to a computer. The intra-observer error was ± 1.8°.

In 1999, Schops et al[26] reported on a reliability study of Penning's Templating method (i.e., functional radiographic analysis of the cervical spine in flexion and extension) as a screening method for segmental instability. Five MDs measured angles of segmental mobility on 20 patients and 20 normal subjects. For segments C3/C4, C4/C5, C5/C6, and C6/C7, the correlation between 5 reviewers showed good to excellent results ($0.6 < \text{Pearson's } r < 0.8$ for good, and $r > 0.8$ for excellent). The selectivity of $p \leq 0.05$ and $p \leq 0.01$ was sufficient to distinguish patients from healthy subjects.

Reliability of Patient Positioning

In 1989, Lind et al[15] studied the range of motion of 70 healthy subjects in maximal flexion-extension and maximal lateral flexions. The range of motion was measured with a compass placed on the subject's head. The intra-observer error was ± 6° for positioning.

Ordway et al.[20] compared dynamic films to two other methods of measuring end-range of motion of cervical flexion, extension, protraction, and retraction. They determined that because end-range cervical flexion and extension include contributions from the upper thorax, true cervical motion must be measured from an internally referenced, or landmark-based methodology.[20] This includes radiography so as long as the data to be extrapolated from the dynamic films are relative to the patient's anatomy on the film (i.e. C2 vs. C7 tangent) and not related to the edge of the film (i.e. atlas plane line to horizontal). Alternatively, if the horizontal

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or vertical is required, then the patient's upper thorax should be fixed or standardized to minimize the upper thorax contribution.

Pediatric Uses of Cervical Flexion-extension Views

In 1993, White et al[30] reported on 17 pediatric patients with Downs syndrome. They stated that measurement of the atlas-dens interval is the radiographic standard for identification of patients, with Downs syndrome, who are at high risk for neurologic injury from spinal cord compression. They used MRI, extension plain radiographs, and lateral flexion radiographs. They stated that neural canal width is a better predictor of potential spinal cord compression than atlas-dens interval or clivus-posterior odontoid process distance.

In 2005, Pitt and Thakore[23] reported on a review of 51 papers (32 from Medline and 19 from Embase) concerning utility of flexion/extension views of cervical spines in children with neck injuries. They determined that "Best Evidence" came from just three studies.[6,25,32] They stated that if the neutral static cervical spine radiograph is normal, then flexion-extension cervical spine radiography is unlikely to be abnormal.

Diagnostic Capabilities

The flexion-extension stress films are useful in determining antero/retro-listheses, hypo/hyper-mobility, evidence of instability, aberrant motion at levels other than C0/C1-C7/T1, articular fixation, or other disabilities of the articulations of the head and neck.[10,17,18]

The usefulness of the 'dynamic study' is critical when one considers that a normal appearing neutral lateral cervical view does not exclude ligamentous injury.[2,7,8,16,19,24,27,29] In fact, the determination of soft tissue and diskoligamentous injuries using plain cervical spine radiographs is poor.[13,29] Additionally, it has been found that slight displacements or other subtle, yet significant findings from static lateral films which are indicative of more severe pathology, are often initially overlooked or so-called, 'hidden'.[7,29] This is why use of stress films are encouraged especially after trauma such as whiplash[34] or polytrauma[28] or to fully appreciate effects of degeneration, muscle spasm, aberrant intersegmental mechanics, and areas vulnerable to focal stress.[17]

Cervical spine dynamic studies often correlate with findings from MR. For example, as mentioned previously, White et al.[30] found good agreement when measuring neural canal widths on x-ray with that found on Down's patient's corresponding MRI.

In 2002, Giuliano et al[9] reported on 200 subjects, 100 normal's versus 100 cervical spine trauma cases. They reported that the normal range of motion was 50° ± 6.5° in flexion and 60° ± 6.5° in extension. They found loss of lordosis in 4% (4/100) of normal's and 98% (98/100) in the patient group. They reported finding 2% (2/100) of normal's had asymptomatic disc herniations, while disc herniations were observed in 28% (28/100) in the patient group. They reported that normal subjects showed a stepwise segmental motion pattern that started at C1-C2 and transmitted to the lower cervical segments, while trauma patients differed from this normal pattern.

Validity

Sagittal Plane Cervical Spine Instability

Different studies indicate different criteria for spinal instability.[35-42] One study indicates 1.5 – 2.0 mm of translation is clinical instability in live humans. Subluxation greater than 2 mm in men 18 to 40 years of age may be a useful variable for further study as an indicator of ligamentous injury.[35] However, current scientific thought is that a segmental translation of

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3.5mm or more on a neutral lateral cervical or flexion/extension radiographs is evidence of ligamentous instability.[36,37] It must be bourne in mind that this 3.5 mm considers a 30% magnification factor and thus the ‘true’ value would be 2.7mm.[36,37] See Figure 3A for sagittal plane translation measurement. It should be noted that such translations when greater than 1.5 mm and found on a neutral lateral cervical are considered to be abnormal; this is a common misconception.[43]

On flexion/extension radiographs, the lower cervical levels (C2-C7) should have a combined segmental rotational movement less than 20°; greater than 20° is suggestive of ligamentous instability.[36-38]

On the neutral lateral cervical radiograph and/or flexion extension radiographs, two more radiological signs, acute kyphotic segmental angulation and ‘gapping’ of the spinous processes, are indirect evidence of ligamentous damage.[36-41] Biomechanical studies have determined that a segment should not be flexed by more than 11° relative to the segment below using segmental Cobb (endplate) lines.[36-39] However, studies using posterior body lines, have found that kinking (kyphosis) of 10° or greater is the limit and/or fanning of the spinous processes of 12mm or greater.[40,41] For example, Griffiths et al[40] found that a 10° angle or greater on the lateral cervical radiograph (flexion and/or neutral) had good sensitivity and specificity in differentiating a motor vehicle injured cohort from normal controls. Figure 3B shows segmental endplate and posterior body lines for an instability assessment.

Cervical injury should be classified as "major" if the following radiographic and/or CT criteria are present: displacement of more than 2 mm in any plane, wide vertebral body in any plane, wide interspinous/interlaminar space, wide facet joints, disrupted posterior vertebral body line, wide disc space, vertebral burst, locked or perched facets (unilateral or bilateral), "hanged man" fracture of C2, dens fracture, and type III occipital condyle fracture.[42]

Often, the upper cervical region is not fully assessed for instability on flexion/extension radiographs. At least 3 distances should be measured in the upper cervical spine on flexion/extension radiographs for an instability analysis. See Figure 3C for upper cervical translation measurements.

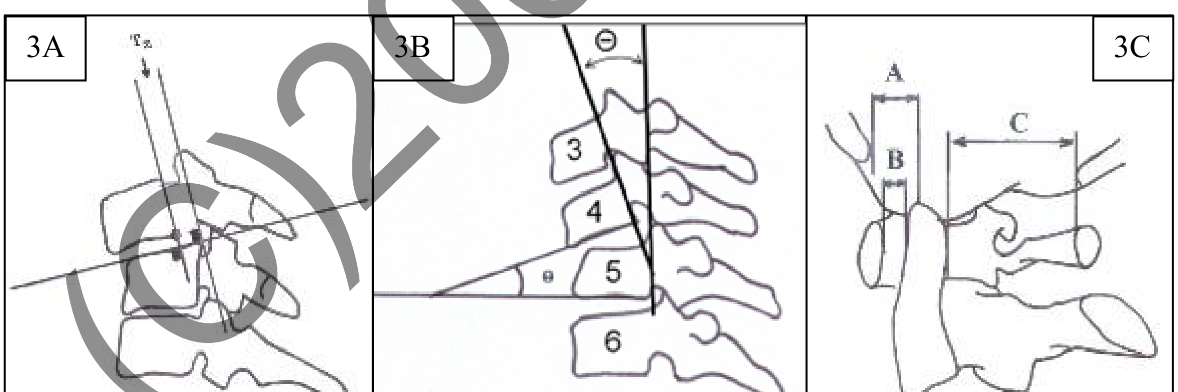

Figure 3A-C. In A, sagittal translation is shown of juxtapositioned vertebra. This measurement should not exceed 3.5 mm accounting for a 30% magnification. In B, two methods of segmental angulation measurement are shown. For the Cobb lines, the measurement should not exceed 11°; while for the posterior body lines, the measurement should not exceed 10°. In C, 3 translation measurements are shown for stability assessment of the upper cervical spine. Measurement A is between the superior tip of the dens and the anterior aspect of the foramen magnum (clivus), this should be between 4-5 mm. Measurement B is the atlanto-dental interspace, this should not exceed 4 mm in adults. Measurement C is the spinal canal sagittal diameter between the posterior aspect of the dens and the anterior aspect of the posterior ring of C1, this should not be less than 13 mm. *Adapted from Panjabi et al[36] and White and Panjabi.[37]*

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Instability check list for cervical spine flexion/extension radiographs (Figure 3A-C):[35-43]

1. Flexion/extension range of motion greater than 20° (any level C2-C7),
2. Segmental flexion angle of greater than 10-11°(Posterior body vs. Cobb),
3. Vertebral body translation of 2.5-3.5 mm or more on flexion/extension,
4. Decreased anterior disc height,
5. Increased posterior disc height,
6. Interspinous space greater than 12 mm,
7. Clivus to dens distance of greater than 4-5 mm,
8. Posterior C2 dens relative to anterior C1 posterior ring less than 13 mm,
9. Atlanto-dental interspace of greater than 4 mm.

Chiropractic Usages of Cervical Flexion-Extension Radiographs

Before Penning's 1978 publication, "Templating" flexion-extension views was taught in Radiology courses at some Chiropractic Colleges.[1] In 1985, Henderson and Dorman[10] reported on normal values, instability, and functional blockage for cervical motions on flexion and extension views.

Regardless of Chiropractic Technique, many doctors evaluate dynamic lateral cervical films to ascertain more data on the cervical region to help determine more and less appropriate care options.[44-46] For example, stress films may be used to identify hyper-mobile joints that may dictate adjusting to areas other than the affected joint complex, or hyper-mobile segment that translates into the canal upon extension would be a contraindication for certain treatment techniques utilizing only an extension moment applied to the cervical spine.

Chiropractic Outcome Studies

Dynamic flexion-extension studies may also be used for pre and post-treatment evaluation; i.e. a quantitative improvement in the global/segmental range of motion or a qualitative improvement in the dynamic function of the neck.[44-46]

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B. Thoracic Views

10. AP Thoracic Radiographic View

RECOMMENDATION

The AP Thoracic Radiographic view is indicated for the routine quantitative assessment of the biomechanical components of vertebral subluxation. This radiographic view has reliability, validity and clinical outcomes data that evidence its clinical utility in clinical chiropractic practice. When using this radiographic view a baseline value of the biomechanical component of spinal subluxation should be determined prior to the initiation of chiropractic treatment intervention. In this manner, response to care can be determined.

Supporting Evidence: Clinical Levels I, IV, V, Reliability Studies Class 1 and 2, Population Studies Class 1 and 2, Biomechanics, and Validity.

PCCRP Evidence Grade: Clinical Studies = B, C, D.

Introduction

Chiropractors have been taking radiographic images of the human spine since 1910,[12] just 15 years following the invention of x-rays by William Roentgen. The human thoracic spine is viewed in the frontal or coronal plane on radiographs using either the anteroposterior (AP) or posteroanterior (PA) direction. The AP/PA Thoracic radiographic view can be taken with the patient standing (erect) or supine. It is customary for the chiropractor to take these films in an erect, weight-bearing position (**Figure 1**) as opposed to the supine positioning that is more prevalent in a hospital setting.

Usually, the AP/PA Thoracic radiographic view is taken with the tube and grid cabinet distance at 40 inches. The grid cabinet, or bucky, is vertically positioned such that the top is approximately two inches above the C7 spinous process. The central ray is centered to the cabinet. Many different measurements have been described over the years by both chiropractors and medical physicians to evaluate the biomechanical configuration of the thoracic spine. We will review the most common of these markings and measurements and discuss the reliability and validity of such evaluation and outcome assessment techniques.

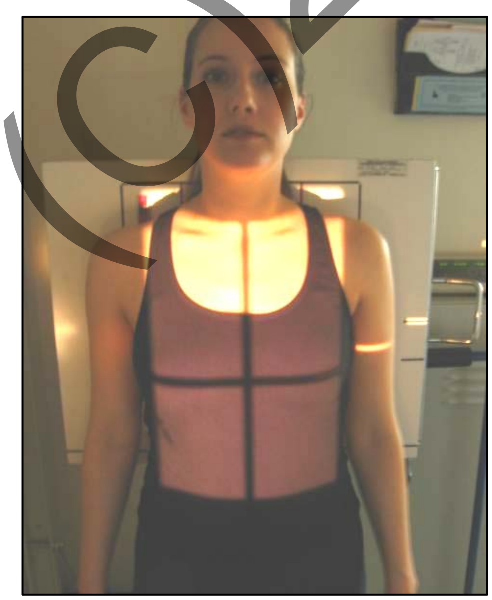

Figure 1. Standing patient position for AP thoracic spine radiographic view.

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Many Chiropractic Techniques require mensuration of angular rotations and linear distances on radiographs to assist in the direction of treatment for a particular patient. The angles and distances are ascertained by means of the construction of lines drawn on the AP/PA Thoracic radiograph. In regards to the Chiropractic adjustment, the measurements obtained may dictate how the patient is positioned for adjusting, where the adjustive force is applied, what line of drive is used, etc... The adjustment can be manual, instrument assisted or by drop table means. In addition to the different corrective forces applied to the thoracic spine through the spinal adjustment, other means of correction have been proposed that are within the scope of practice in most areas, including spinal traction and exercises. Furthermore, many of these chiropractic "techniques" require that a post treatment x-ray be obtained to verify a successful intervention; i.e., a reduction in the subluxation misalignment.

Reliability of Line Drawing Methodologies

Cobb Method: The most commonly reported method of measuring displacement of the AP/PA thoracic spine from normal is called the Cobb method. The Cobb method was first described in 1948 for the evaluation and quantification of scoliosis deformity.[5] (**Figure 2)**.

Kuklo found that most examiner error when producing these lines and angles occurs when identifying the two end vertebra.[14] However, there is minimal magnitude of error even when different levels are selected. This was found to be true because the endplates are nearly parallel when it is most difficult to determine the proximal and distal end vertebrae.[4,14,21,38] The Cobb angle is produced by first constructing lines along the superior endplate of the superior end-vertebra and the inferior endplate of the inferior end-vertebra, as shown in **Figure 2**. Then, perpendiculars are constructed to each of these lines such that they intersect forming the "Cobb angle". The same protractor and other measuring devices, such as a ruler, should be used when evaluating films to reduce potential error, as described by Morrissy.[21]

Because of the potential for examiner error, the reproducibility of producing the Cobb angle has been studied extensively, with inter-observer variability between 0.84°- 8.0° and excellent intra-examiner reliability.[4,6,14,21,37,38] However, as stated above, when the end vertebra are standardized (as in clinical practice), the errors are extremely small.[14,37] For example, Lantz, a chiropractor, demonstrated a minimal 0.6° margin of error for intra-examiner test-retest reliability.[14] Wilson et al found a SEM of 0.84° for 38 examiners measuring 1 PA x-ray.

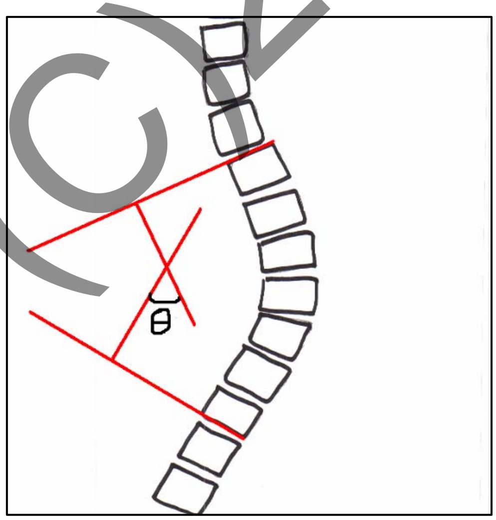

Figure 2: Cobb angle measurement of thoracic scoliosis. The "Cobb angle" is produced from the intersection of perpendiculars from the endplates of the superior and inferior end-vertebrae.

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Risser-Ferguson Method: **See figure 3**. The Risser-Ferguson method of analyzing the frontal plane of the thoracic spine is less commonly reported in the literature. In an opinion paper, Kittleson and Lim[39] argued that the Riser-Ferguson method should be used for curves under 50° and the Cobb method for those curves over 50° due to validity issues. Stokes et al[27] found that the Risser-Ferguson method of analysis produces an average angle that is 1.35 times less than the Cobb angle.

At least two investigations have reported examiner errors and reliability for the Risser-Ferguson method.[27,40] Both investigations[27,40] reported good to excellent examiner reliability for the Ferguson method.

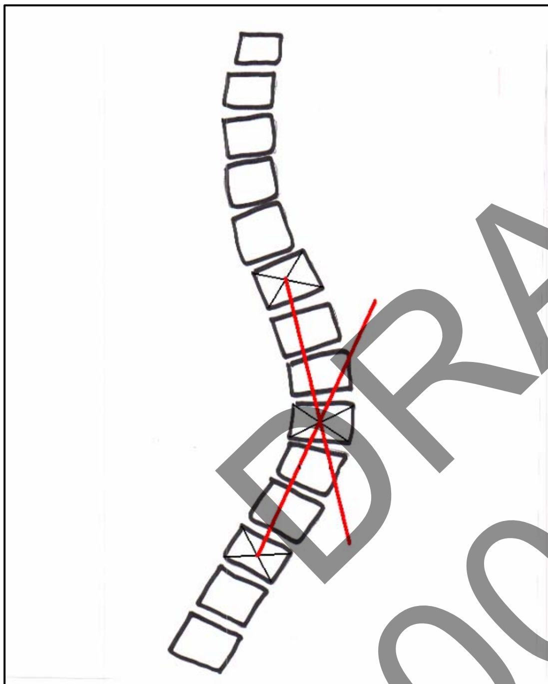

Figure 3: Risser-Ferguson anglular measurement of thoracic scoliosis. The “Risser-Ferguson angle” is produced from the intersection of lines drawn superior and inferior from the apical vertebra center to the center of the two end vertebrae.

Rib Vertebral Difference (RVAD): **See Figure 4**. Mehta first described a method to measure axial rotation of the apical segment in a thoracic scoliosis in 1972.[18] The method requires identification of the apical vertebra. The associated ribs are identified. A line is drawn from the midpoint off the neck of each rib to the midpoint of the head of each respective rib. A perpendicular is drawn to the middle of either the upper or lower endplate of the selected thoracic vertebra. The intersection of each rib line with the perpendicular vertebral line is the rib vertebral angle (RVA). The difference of the concave measurement and the convex measurement is the rib vertebral angle difference (RVAD). The reliability of the markings was not discussed by Mehta in the original article.

However, in 1997, McAlindon and Kruse[16] demonstrated intra-observer error of 4.4° and inter-observer error of only 3.6°. Four observers measured the angle of 50 radiographs. This procedure was repeated a second time 2 days later and a third time 2 days after the second.

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Clavicle angle: **See Figure 5.** The clavicle angle is defined as the angle produced by the intersection of a horizontal line and a line connecting the highest two points of each clavicle.[13] This is described as a means of assessing the proximal thoracic scoliosis and shoulder height.

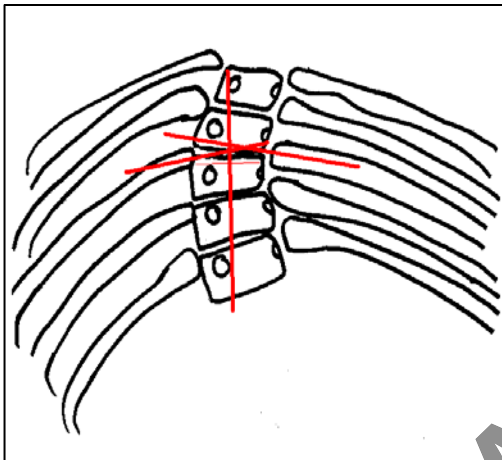

Figure 4: The rib-vertebra angle (RVA). The RVA is determined by measuring the angle formed from the "rib line" (from the right and left ribs) as they intersect a line perpendicular to the endplate. The rib vertebra angle difference (RVAD) is the difference from concave to convex side. Only the apical segment is evaluated.

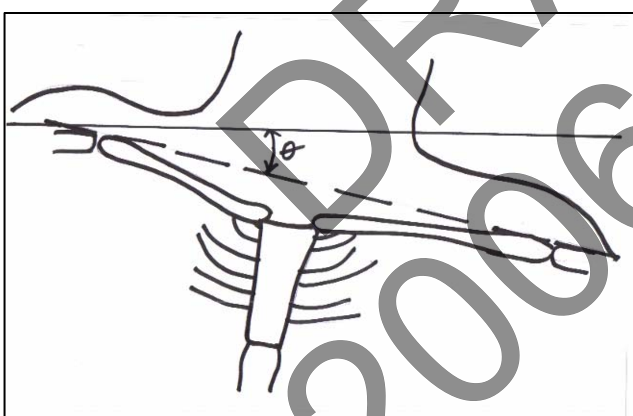

Figure 5: Clavicular angle. The clavicular angle is formed by the horizontal angulation of a line drawn from the two highest points of the clavicles. *Adapted from: Kuklo TR, Lenke LG, Graham EJ, et al. Spine 2002;27(18):2013-2020.*

Reliability of Patient Positioning

Several investigations have been performed on the test re-test reliability of patient positioning for the AP/PA full spine or sectional AP thoracic measurements.[23,40-45] Problematically, many authors have misrepresented the scientific evidence on this topic and offer their Class V opinion that radiographic positioning is a significant source of error for AP/PA thoracic spine measurements.[41,42] For example, Capasso[41] claimed that difference in the curve of up to 17° can occur between an AP standing radiograph compared to a that obtained with a positioning device. A review of pertinent studies provides a different conclusion.

In 1978, Dawson et al[43] took repeated AP full spine x-rays on 60 scoliosis patients in the upright and the scoliosis chariot (SC) positioning device on the same day. Fourteen subjects had 2 scoliosis chariot x-rays exposed within 5 minutes of each other (3 total x-rays in each of these 14 subjects). Average differences in Cobb angle between the AP full spine and SC view were

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3.4°-7.5° (increasing as curve magnitude increased). The difference in 2 repeated SC views were all within ± 3°. The authors concluded that SC views for scoliosis were more repeatable.[43] However, repeated AP full spine views were not performed on the same subject. Therefore, this study shows that as long as the clinician uses the same positioning procedures, then high examiner reliability will be found. This study[43] was misinterpreted by Capasso.[41]

In 1982, Desmet et al[44] took AP and PA full spine x-ray views of 78 scoliosis patients with an average time of 5-15 minutes between radiographs. Strong correlation between curve measures on AP vs. PA full spine films was found; r = .960. The PA view demonstrated a mean increased curve of 1.71° compared to the AP view. In 5/128 curves a 9°-13° increase, in 19/128 curves a 6°-8° increase, and in 4/128 curves a 6°-8° decrease on the PA film was found. The difference in curve values is due to projection of endplates on PA vs. AP films. However, this study does not indicate that positioning is a source of error as long as the same procedures are followed.

In 1995, Kohlmaier et al[45] took 2 AP full spine x-rays (standing and in a positioning device) of 100 scoliosis subjects. They concluded that the balance-like positioning device can standardize spine X-rays when the patient is standing, providing better reproducibility, more accurate prognostic aspects and fewer ionizing hazards. However, Kohlmaier et al did not actually investigate the repeatability of the same position on each subject therefore no conclusions can be drawn.

In order to investigate positioning errors, Sevastikoglou and Bergquist[40] took 17 frontal plane radiographs of 2 scoliosis skeletons: neutral, rotation up to 10° left/right and 5 cm elevation or depression of the tube height. Two examiners assessed the curves using the Cobb and Riser-Ferguson methods. They found little effect of rotation up to 10° and alteration in tube height by 5 cm on curve magnitudes. Differences in curve measurements hardly surpassed the error of the measurement techniques themselves. Average error for specimen 1 had the largest values: 1.15° ± 0.98° for Ferguson's method and 2.06° ± 1.09° for Cobb's method. This information[40] was misinterpreted and inaccurately reported by Capasso et al.[41]

Pruijs, et al,[23] investigated the repeatability and reliability of thoracic, thoracolumbar and lumbar Cobb angle measurements by studying two sources of error: the production of the radiograph and drawing/measuring the lines/angles. Regarding the production of the radiographs, the investigators compared serial radiographs in patients who underwent surgical spinal fusion for scoliosis and therefore had a fixed spinal curve. They discovered that the production of the series of radiographs produced a standard deviation in the Cobb angle of only 3.2°. This is often less than the standard error of measurement, as discussed previously in some studies. In other words, the measurement method may not be sensitive enough to detect any 'true' differences in the curve caused by positioning.

Based on the above review, it is the consensus of the PCCRP panel that positioning procedures for exposing the AP/PA thoracic radiographs are reliable as long as the same procedures are followed on initial and repeat films.

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Diagnostic Capabilities

The AP and PA thoracic views have been used to evaluate many anatomical structures visible on the film. The thoracic spine, ribs, clavicles, sternum and scapulae are bony structures visible on the frontal plane radiographs of this area. Soft tissue structures, such as the heart and lung fields, are also visible on these films.

Validity

Multiple investigations have found correlation and predictive validity of the AP/PA Thoracic radiographic alignment to a variety of health related conditions A review of these investigations is provided below. The AP/PA Thoracic view has the following correlations:

1. Cobb angle magnitude can predict scoliosis progression,[26]
2. Magnitude of curve displacement correlates to rate of osteoarthritis,[24,29]
3. Magnitude of diplacement correlates to health, pain, and disability,[9,28,36,46-48]
4. RVAD predicts tendency of progression in infantile scoliosis,[3,18]
5. Clavicular angle is predictive of shoulder height.[13]

Cobb Validity

The magnitude of scoliosis as determined by the Cobb angle on plain films has been shown to predictive of progression of the scoliotic curve. In a study of 85,627 children screened for scoliosis, it was shown that in those with scoliotic curves > 30° Cobb angle, the incidence of progression (increasing Cobb angle > 5° from visit to visit) was 48%. For curves 10-20° the rate was lower at 11.9% to 20%, respectively.[26]

Richter, et al,[24] studied the rate of osteoarthritis in a group of 100 scoliosis patients with an average age of 19 years and ranging from 12-30 years old; this group did not include anyone with so-called "age-related" osteoarthritis of the spine. The authors found that, "37% of curves less than 20° had osteophytes, and this increased to 53% of curves greater than 40°".[24] Subjects were compared to a control group and were found to have a higher incidence of degenerative changes ($P < .01$). Two observers graded the degenerative changes and there was a close inter-observer correlation. In addition, ten of the films were repeated, without knowledge of previous assessment, by both observers demonstrating good intra-observer reliability. Weinstein,[29] in a 50-year follow-up of untreated scoliosis, showed that 95% of the scoliotic spines demonstrated significant degenerative changes.

Misalignment of the thoracic spine in scoliosis patients, as measured by the Cobb angle, has also been associated with different Health-Related Quality of Life (HRQL) outcome scores. Wilson, et al,[36] found that coronal measures of thoracic curve, including the Cobb angle, were negatively correlated with the following parameters of the Scoliosis Research Society (SRS) outcome assessment questionnaire: Total Pain ($r= -0.22$, $P < .001$), General Self Image ($r = -0.23$, $P < .001$, General Function ($r = -0.18$, $P < .003$) and Total SRS score ($r = -0.22$, $P < .001$). As curve magnitude increase, the scores decreased, i.e., worsened health scores, thus the negative correlation. Asher et al,[46-48] also found that, as a group, pre-operative (untreated) thoracic curves were associated with lower General Function scores ($r = -0.52$, $P < .0013$), Subtotal Score ($r = -0.43$, $P < .0089$) and pain.

In 2002, Freidel, et al,[9] found that, compared to the age-matched general population norms, juvenile females with scoliosis were unhappier with their lives ($P = .001$), had more physical complaints ($P < .001$), had lower self esteem ($P = .01$) and higher depression scores ($P =.021$) than their peers. Adult patients reported more psychological ($P < .001$) and physical impairment ($P < .001$) than compared to the population norm. In a 2005 Japanese study assessing untreated scoliosis patients with the SRS outcome assessment questionnaire, the scores of Pain ($r = -.33$, $P < .0001$) and General Self Image ($r = -0.25$, $P < .0024$) had a significant inverse

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correlation with thoracic curve Cobb angle. The authors also note that, "patients with a thoracic curve Cobb angle of more than 40° had a significantly lower outcome score than those with a thoracic curve Cobb angle less than 40°".[28]

A review of the literature reveals a relationship between Cobb angle magnitude and risk of progression, development of osteoarthritis and different outcome scores of health-related quality of life, including depression, self-esteem, being unhappy with life, and physical impairment. Again, clinically the Cobb angle is measured on plain film radiographs through manually constructed line-drawing technique. This method is widely used in both the chiropractic and medical professions. It is important to note that a recent survey of the intention of chiropractors to manage scoliosis showed that, "in general, the respondents would provide 6 months of 'intensive' chiropractic therapy, then follow the patient for 4 years (near skeletal maturity)."[8] More than 80% of the respondents would use diversified technique, which relies upon radiographic spinal "listings"; while 87% would use "exercises" in their treatment.[8]

<u>RVAD Validity</u>

The rib vertebra angle difference between the concave versus the convex apical level has been shown to have predictive validity in assessment of tendency of progression in infantile scoliosis. A difference of 20° or more is indicative of an 80% chance of progression. Conversely, a RVAD less than 20° is 80% likely to resolve.[18] Some of the progressive cases had initial Cobb angles as small as 12°. The only presenting signs in infantile scoliosis may be postural distortion. The RVAD is the only method reported in the literature, to our knowledge, that has such high predictive validity for the progression of infantile and juvenile scoliosis. If radiographs are not taken on the young patients, who present with no "red flags" other than postural distortion, they could suffer early mortality associated with early onset progressive idiopathic scoliosis.[3]

<u>Clavicular Angle Validity</u>

Kuklo reported on 112 patients assessed and treated for proximal thoracic scoliosis and resultant shoulder imbalance.[13] The clavicular height was the only radiographic variable measured that was predictive for accuracy of shoulder height (measured as the soft tissue shadow on the film) in subjects treated surgically for scoliosis in three out of the four groups studied (P = .0009, .0193, .0716 and .0007).[13]

<u>Outcome Investigations</u>

<u>Level I Studies:</u>

In a randomized controlled-comparison clinical trial, Plaugher et al,[22] investigated the efficacy of Gonstead chiropractic adjusting technique with patients demonstrating essential hypertension and spinal subluxation. The mean change in diastolic blood pressure was -4 in the chiropractic care group. One of the variables in determination of location and type of adjustment was spinal misalignment as measured on AP plain film radiographs.

<u>Level II Studies</u>: No Level II studies could be found.

<u>Level III Studies</u>: No Level III studies could be found.

<u>Level IV Studies</u>:

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Alcantara et al[1] reported on a 74-year-old geriatric female patient with complaints of mid thoracic and low back pain. Radiographic evaluation revealed acute compression fracture of T8, as well as subluxation "listings", including levels T5 and T8, as measured from the AP image of the thoracic spine. Comparative radiographs were obtained at 4 ½ weeks, demonstrating correction of the T5 and T8 levels. The patient was adjusted a total of 25 times from initial to the comparative x-ray.

In another case study a 63-year-old male patient presented with myasthenia gravis.[2] Primary subluxations were identified on the AP radiograph image at the C7 and T4 spinal levels. The patient was adjusted based upon these spinal listings. The myasthenia gravis symptoms were essentially resolved through subluxation correction. The patient was adjusted 33 times then told to come in 1-2 times a month or on an as-needed basis. The patient reported only mild thoracic and low back pain.

Morningstar et al,[20] reported on the effectiveness of Pettibon methods with a case series of 19 scoliosis cases. Pre-treatment radiographs were taken on each patient and Cobb angles were measured. Post-treatment radiographs were taken 4-6 weeks following their intervention and comparative Cobb angles were constructed. There was an average 17° reduction in the Cobb angle.

Gilmour et al[10] reported on the successful management of patient with a 35º left convex thoracolumbar scoliosis treated using Pettibon corrective procedures. Initial and follow-up outcome measures included a Borg pain scale, a Functional Rating Index, a balance test, and radiographic analysis. After six weeks of treatment, the post treatment radiograph revealed a 20º left convex thoracolumbar scoliosis (15 reduction in the curve), as well as decreases in the Borg pain scale (6 to 2) and Functional Rating Index score from 18/40 to 7/40.

Joy et al[11] reported on the successful management of 3 patients with idiopathic or scoliosis secondary to Scheuermann's disease. Patients were treated with spinal adjustments and head/body weighting exercises for 12 weeks. A reduction in Cobb angles of 13°, 8°, and 16° was found in the 3 cases respectively over 12 weeks of treatment.

<u>Adjunctive Procedures Used by Chiropractic Clinicians</u>

Eighty Six percent (86%) of chiropractors report that they would incorporate exercises in their treatment plan for a patient with idiopathic soliosis.[8] Miyasaki[18] studied the effect of an exercise forcing the thorax into forward flexion. This exercise was evaluated for its effect on apical rotation and the lateral flexion deformity while they were in the Milwaukee brace. They found that thoracic Cobb angles were larger while standing passively in the Milwaukee brace as compared to the smaller Cobb magnitude while performing the thoracic flexion exercise.

In 1983, Mehta reported on the use of lateral thoracic shifting exercises for scoliosis patients.[16] She reported, that her exercises "are comparable with those reported by braces or electrospinal stimulation". The post treatment Cobb angle had either decreased or remained unchanged in 71% of the patients. For a curve to be "progressive" it must increase in severity by 5º or more in one year. The group considered "most at risk" for progression averaged about 1º worsening per year over the 1.9 years they treated the patients. Mehta states, "thoracolumbar and low thoracic curves respond best to the side-shift, lumbar curves less so, particularly when there is an acute take-off at L5".[28]

In 1999, another group of clinical researchers demonstrated that active "side-shift" exercises were found to have a promising effect on Cobb angle in idiopathic scoliosis patients.[7] The subjects ranged in age from 10-15 years old and had initial Cobb angles ranging 20-32°. The

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subjects performed their side shift exercise regime for more than 4 months. The side-shifting group showed only a 2° increase of Cobb angle after 4 months. They compared these results to a matched historical brace cohort group, which showed a 2° decrease in Cobb angle. Also of importance is the non-compliance of each group. The side-shift group only had 4.5% non-compliance, while the brace group had resulted in 24.2% of the original group not in compliance. This demonstrates the tendency for the adolescent aged patient's preference for non-bracing treatment.

Three dimensional exercise therapy for scoliosis has been utilized on an inpatient setting in Germany at the Katharina Schroth Clinic. In one study, published in 1992, Weiss[34] reports on the effectiveness of the program on 107 scoliosis patients. Exercises designed to reduce the curves were used as was what the author calls "rotational breathing", which is supposed to increase inspired air to the concave areas of the chest by selective contraction of the convex areas of the trunk with the goal of lengthening and mobilizing related soft tissue areas. The average Cobb angle of the primary curve decreased from 43° to 40° and the secondary curve decreased from 28° to 26°. Greater than 97% of the primary curves and over 99% of the secondary curves either decreased in magnitude or remained the same. The group in this study was relatively mature, average age of 21.6 years, and thus at a lower risk for progression.

To test whether positive results could be obtained for patients considered at high risk for progression, in 1997, Weiss et al[30] studied 181 patients at high-risk for progression, that is an average age of 12.7 years, average Cobb angle of 27° and average Riser sign of only 1.4. Follow-up radiographs were obtained at an average of 33 months and Cobb angles were measured. At 33-month follow-up the average Cobb angle was 29°, only 2° worse. Over the course of almost three years, one would expect a "progressive" curve to increase by at least 15°. This team of clinical researchers has reported similar success in various studies.[29,31-33]

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11. Lateral Thoracic Radiographic View

RECOMMENDATION

The Lateral Thoracic Radiographic view is indicated for the routine quantitative assessment of the biomechanical components of vertebral subluxation. This radiographic view has reliability, validity and clinical outcomes data that evidence its clinical utility in clinical chiropractic practice. When using this radiographic view a baseline value of the biomechanical component of spinal subluxation should be determined prior to the initiation of chiropractic treatment intervention. In this manner, response to care can be determined.

Supporting Evidence: Clinical Levels II and V, Reliability Studies Class 1 and 2, Population Studies Class 1 and 2, Biomechanics, and Validity.

PCCRP Evidence Grade: Clinical Studies = B, D.

Introduction

In radiography of the thoracic spine, the lateral thoracic radiographic view is generally one of two primary views. Care should be taken to insure that several structures are visible from the upper thoracic spine superiorly to the thoraco-lumbar junction (T12-L1) inferiorly. In the majority of cases, a lateral lower lung field filter (T7-T12) is needed in order to adequately visualize the entire thoracic spine.

In chiropractic analysis, the lateral thoracic view should be taken in the upright standing position at the standard tube distance of 100 cm (40 inches) with the central ray located approximately at the T6-T7 disc level. For lateral thoracic radiographs, the patient's arms must be positioned out of the field of x-ray view by placing the hands on a rest at iliac crest height[1], by holding arms out almost 90° in front grasping a stand,[2] by folding the hands on top of the head,[3] or by folding the arms on the chest placing the hands in the clavicular fossae.[4]

Since chiropractic clinicians are interested in the alignment of the patient's individual spine, the self balance position seems appropriate to ascertain the patient's unique subluxation alignment. The patient's abnormal sagittal plane posture is left as is, i.e. it is not guided towards an ideal neutral position. **Figure 1** depicts the 'self balance positioning' of a patient with hands on a rest at iliac height, hands and arms straight out in front grasping a pole, hands on top of the head, and with hands in the clavicular fossae in their neutral resting posture.

Reliability of Measurement Methods

The lateral thoracic radiograph measurements include the total curve measurements at a various upper, middle, and lower thoracic levels, sagittal balance (flexion/extension and sagittal translation) of the upper versus lower thoracic levels, segmental thoracic kyphosis values, and thoracic vertebral body wedge angles to assess deformity from fracture or other pathology. These methods have been measured in a multitude of different ways on lateral thoracic radiographs. The Harrison Posterior Tangent, Cobb, Centroid, and length versus width have all been subjected to examiner reliability investigations.[5-14]

Harrison et al[5] investigated the inter- and intra-examiner reliability of the Harrison Posterior Tangent (HPT), Cobb, and Centroid methods for assessment of thoracic kyphosis. Excellent examiner reliability, low standard errors of measurement, and small absolute differences of observers' measurements were found. **See Figures 2-4**.

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Carman et al[6] and Jackson et al[7] have investigated the reliability of the Cobb Method for measurement of thoracic kyphosis. Collectively these studies indicate that measurement of the lateral thoracic radiographic alignment has excellent observer reliability for a variety of methodology.[5-14]

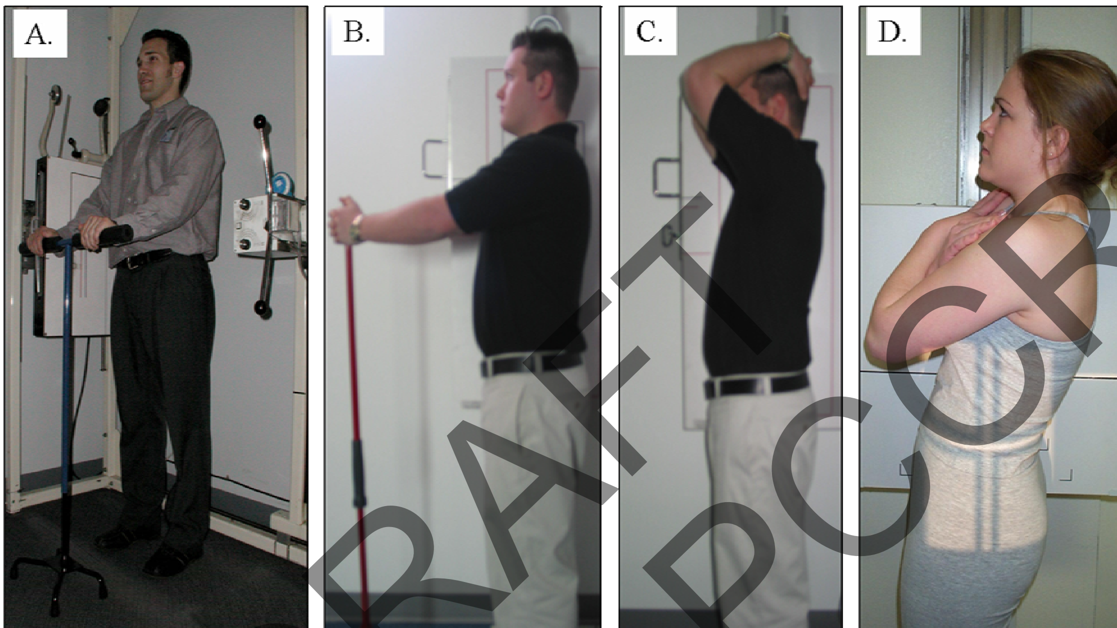

Figure 1 A-D. Self balance position for the lateral thoracic radiograph. In A, the patient assumes their neutral postural balance and then the arms are bent at the elbow and shoulder approximately 135° and the hands are placed on a rest at iliac crest height. In B, the patients arms are flexed nearly 90 at the shoulder and the hands are placed on a pole. In C, the arms are abducted, elbows flexed, and hands folded on the head. In D, the patient assumes the 'self balance position' and then the arms are folded on the chest placing the hands in the claviular fossae.

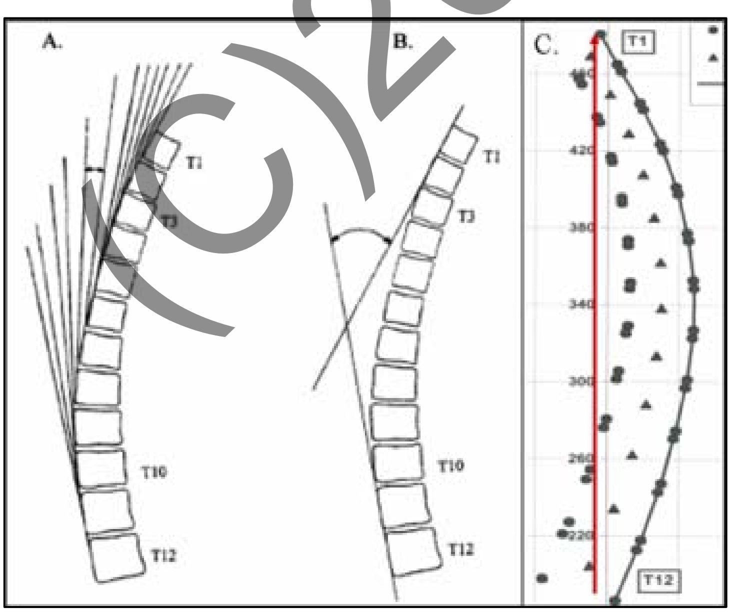

Figure 2. The Harrison Posterior Tangent (HPT) method. In A, HPT lines are drawn along the posterior body margins of each vertebra from T1-T12 to measure the segmental contributions to thoracic curvature. In B, HPT lines are drawn along the posterior body margins of T1 & T12, in order to measure the total curve angle. In C, the vertical alignment of T1 centroid is compared to T12 centroid for sagittal balance assessment. The HPT method for measuring lumbar lordosis has high reliability, low standard errors of measurement, and small absolute differences of observers' measurements.

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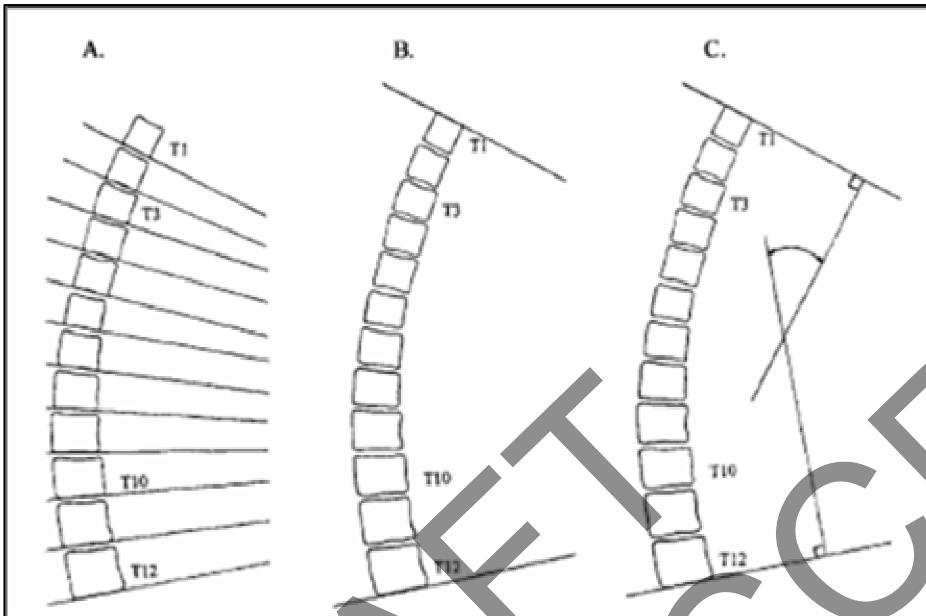

Figure 3. The Cobb Method can be drawn with 4-lines or 2-lines and from a variety of different levels. In A, segmental cobb angles are drawn along each inferior endplate to measure the segmental contributions to thoracic kyphosis. In B & C, construction of the total kyphosis curve angle is shown using T1 superior endplate and T12 inferior endplate lines. These methods have good to excellent inter and intra examiner reliability.

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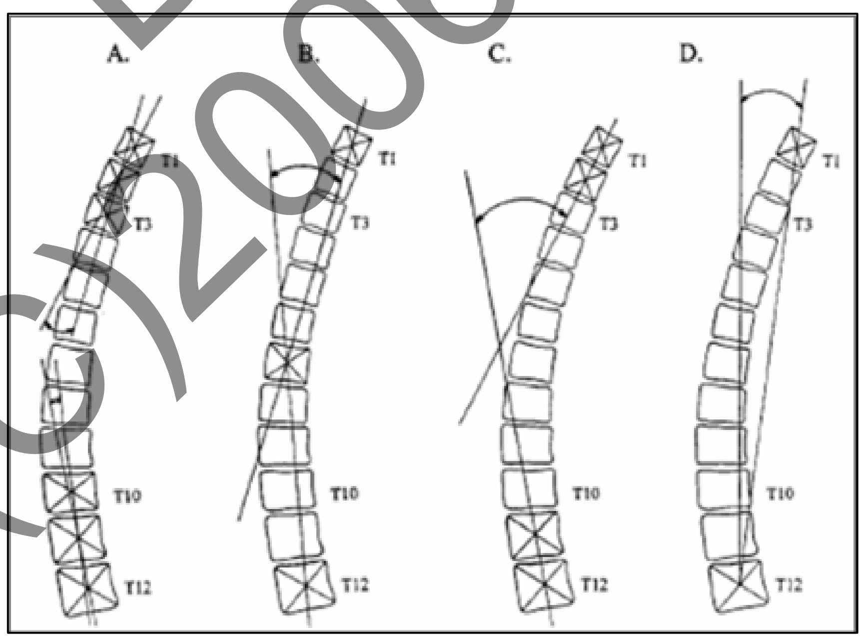

Figure 4 A-D. In A-D, the Centroid method for total curve angle and segmental curvature is shown. However, the Centroid method cannot actually measure true segmental alignment as it requires three vertebrae to construct one angle. These methods have good to excellent inter and intra examiner reliability.

Repeatability of Patient Positioning

At least five studies have performed repeat radiographs of the lateral thoracic spine in the same subject.[1,7,12,15,16] Without exception, these five investigations clearly demonstrate that lateral thoracic alignment on follow-up radiographs is repeatable even when films were taken by different examiners months or years apart.

Stagnara et al[1] stated, "*For subjects undergoing clinical and X-ray examinations at intervals of five to ten years, and where no growth or pathologic deformation factors are to be taken into to account, the clinical and X-ray measurements of kyphosis and lordosis are remarkably constant to within a few degrees, provided the position is clearly stipulated.*"

Jackson et al[7] took initial and follow-up lateral full-spine radiographs in 20 volunteers and 20 low back pain patients taken 66 months and 2 weeks apart, respectively. Very little variation in the thoracic kyphosis from T1-T12 was found between the 1st and follow-up x-ray with ranked correlation coefficients of $r = 0.81$ for volunteers and $r = 0.79$ for patients.

Singer[12] compared 22 pairs of in vivo and post mortem lateral thoracic films. The time difference between the films ranged from 3 days to 77 months. No statistically significant differences were found in the magnitude of thoracic kyphosis using the Cobb method and a computer assisted curvature measurement.

Milne and Williamson[15] reported no significant change in radiographically determined thoracic kyphosis measurements for initial and average 5 year follow-up in 261 elderly subjects.

Using a statistical model with Cartesian coordinates representing the path of the vertebral bodies of the thoracic and lumbar spine in the sagittal plane, Beck and Killus stated, "*…several X-rays of the same individuals furnished reproducible results, even though they were taken years apart.*"[16]

Diagnostic Capabilities

When properly performed, the lateral thoracic radiograph will provide visualization of several structures, subluxation abnormalities, anomalies, and pathologies. The vertebral bodies, disc spaces, articular pillars, and spinous processes should all be visualized. The lateral thoracic view provides the chiropractic clinician with valuable information including:

1. Total thoracic kyphosis,
2. Segmental contribution to kyphosis,
3. Breaks in Georges' line or sagittal plane translation of the posterior vertebra and spinous lamina junction for a general stability analysis,
4. Vertebral body wedge angles for pathology and fracture analysis,
5. General sagittal balance alignment of the upper vs. lower ribcage,
6. Stages of disc, ligament & vertebral body degenerative pathologies,
7. Spinal canal dimensions,
8. A number of other anomalies, fractures, and instabilities.

Validity

Multiple investigations have been performed and found correlation and predictive validity of the lateral thoracic radiographic alignment to a variety of health related conditions including:

1. acute and chronic back pain,[17-19]
2. psychological distress due to cosmetic appearance of deformity,[20,21]
3. hyper cervical lordosis,[12,22]

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4. stress/strain relationships and degenerative joint disease (DJD),[23-26]
5. impaired rib cage expansion during respiration,[27]
6. altered shoulder alignment & gleno-humeral pathology,[28]
7. physical disability & functional impairments,[18,29-32,49]
8. risk of deformity progression and vertebral body fractures,[20,25,33]
9. development of vertebral body wedge deformities,[50,51]
10. risk of scoliosis development & progression,[34,35]
11. organ prolapse,[36]
12. longevity.[15,37-39]

It is the consensus of the PCCRP panel that the number and quality of investigations finding a correlation between the lateral thoracic radiographic alignment and the conditions in the above 12 categories is of adequate quality. Thus, we conclude that the lateral thoracic radiographic alignment has positive correlation to and predictive validity for these 12 categories.[12,15,17-39,49-51]

Outcome Investigations

Several outcome investigations have been performed using a variety of conservative procedures aimed at restoration of the normal thoracic kyphosis in a variety of patient pain and health disorders.[21,40-48] The majority of these reports combine exercise, bracing, and/or passive 3-point bending traction with postural awareness in a multimodal treatment approach to reduce sagittal plane thoracic deformities. Collectively, these reports indicate that patients benefit from a multi-modal physical and chiropractic treatment approach aimed at improvement and/or restoration of an abnormal sagittal thoracic spinal alignment.[21,40-48]

<u>Level I Studies</u>: No Level I studies using chiropractic intervention could be located.

<u>Level II Studies</u>:

In a small clinical trial, chiropractic adjustments combined with rehab procedures compared with rehab procedures alone was found to be superior in the reduction of thoracic hyper-kyphotic curvature.[40]

<u>Level III Studies</u>: No Level III studies using chiropractic intervention could be located.

<u>Level IV Studies</u>: No Level IV studies using chiropractic intervention could be located.

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C. Lumbar Views

12. AP Lumbar Radiographic View

RECOMMENDATION

The AP Lumbar Radiographic view is indicated for the routine quantitative assessment of the biomechanical components of vertebral subluxation. This radiographic view has reliability, validity and clinical outcomes data that evidence its clinical utility in clinical chiropractic practice. When using this radiographic view, a baseline value of the biomechanical component of spinal subluxation should be determined prior to the initiation of chiropractic treatment intervention. In this manner, response to care can be determined.

Supporting Evidence: Clinical Levels II, IV,V, Reliability Studies Class 1 and 2, Population Studies Class 1 and 2, Biomechanics, and Validity.

PCCRP Evidence Grade: Clinical Studies = B, C, D.

Introduction

The human lumbar spine and pelvis is commonly viewed in the frontal (coronal) plane for assessment of structural alignment. The AP Lumbar radiographic view can be taken with the patient standing (erect) or supine recumbent. It is customary for the chiropractor to take these films in an erect position (**Figure 1**) as opposed to the supine recumbent positioning that is more prevalent in a hospital setting.

This view is taken with the tube and grid cabinet distance at 40 inches. The central ray is adjusted vertically to approximately 1-2 inches below the top of the iliac crest (level of L3). The grid cabinet, or bucky, is vertically positioned to accommodate the central ray. Many different measurements have been described over the years by both chiropractors and medical physicians to evaluate the biomechanical configuration of the lumbar spine and pelvis on the frontal plane radiograph. We will review the most common of these markings and measurements and discuss the reliability and validity of such evaluation and outcome assessment techniques.

Figure 1. **Positioning for AP Lumbar Radiograph.** The patient is positioned with the pelvis centered to the bucky. The central ray is aimed at the L3 level.

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Some authors advocate the use of the PA Lumbar radiograph in order to reduce radiation exposure levels to 'sensitive' organs as well as improved visibility of certain lumbar vertebral landmarks.[50] The information presented in section VII, however, indicates that fears of increased radiation exposure are without scientific merit. Furthermore, the increased abdominal size of some patients makes the PA Lumbar radiograph impractical. Still either the PA or AP view would be acceptable pending the clinician's preference.

Many Chiropractic Techniques use measurements on the AP lumbar/pelvic view to help dictate the course of treatment for the patient. This determination may include how the patient is positioned for adjusting, where the adjustive force is applied, and what the line of drive will be. The adjustment can be manual, instrument assisted or by drop table means. In addition to the different corrective forces applied to the lumbar spine through the spinal adjustment, other means of mechanical correction have been proposed, such as spinal traction. Furthermore, these techniques require that a post treatment x-ray be obtained to verify a successful intervention; i.e., a reduction in the subluxation misalignment.

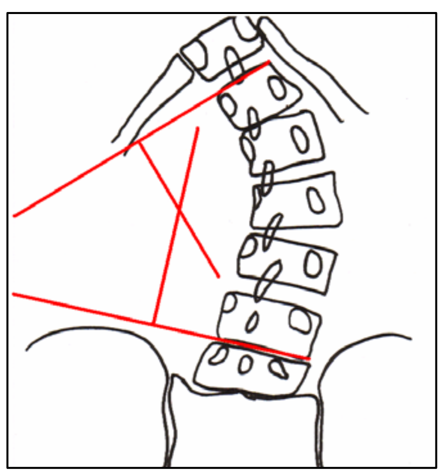
Reliability of Line Drawing Methodology

Cobb angle: The most common method of measuring the deviation of the lumbar spine from normal on this film is called the Cobb method. The Cobb method was originated by Cobb, a medical physician, in 1948.[8] Lines are constructed along the superior endplate of the superior end-vertebra and the inferior endplate of the inferior end-vertebra; perpendiculars are constructed to each of these lines such that they intersect forming the "Cobb angle". See **Figure 2**.

There are several sources of error in the production of the Cobb angle, but selection of the end vertebra of the scoliosis is the most significant.[7,19,29] Using different protractors to measure the same angle has been shown to produce varying results.[29] Therefore, the same protractor and other measuring devices, such as a ruler, should be used when evaluating films.

The reproducibility of manual construction of the Cobb angle has been studied extensively, with variability between 0.84° - 8.0° and excellent overall reliability.[5,7,13,19,29,49,51-53] Zmurko, et al,[49] studied the intra- and interobserver error of Cobb angle measurements on digital versus traditional radiographs. The films were evaluated by four examiners on two occasions two weeks apart. The authors found that, "There was no statistical difference in the mean error index, the variability in choosing the end vertebra on successive measurements, between the digital and traditional groups".[49] Similarly, there was no significant difference in the intraobserver or interobserver variance between the digital and traditional groups. They concluded that, "Digital radiographs are comparable to the use of traditional radiographs for following patients with adolescent idiopathic scoliosis".[49]

Figure 2. **The Cobb Method of Scoliosis Measurement.** The "Cobb angle" is the angle produced by intersection of perpendiculars constructed from two lines drawn along the superior endplate of the upper end vertebra and the inferior endplate of the lower end vertebra.



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Gonstead Measurements: In Gonstead technique, endplate 'wedge angles' are used to assess juxtaposition segmental subluxation as well as overall Cobb angle alignment. Plaugher et al,[31] studied the reliability of Gonstead radiographic analysis for several variables of static radiological alignment of the lumbar spine/pelvis. They found that all variables had high inter- and intra-examiner reliability, ($p<0.001$).[31]

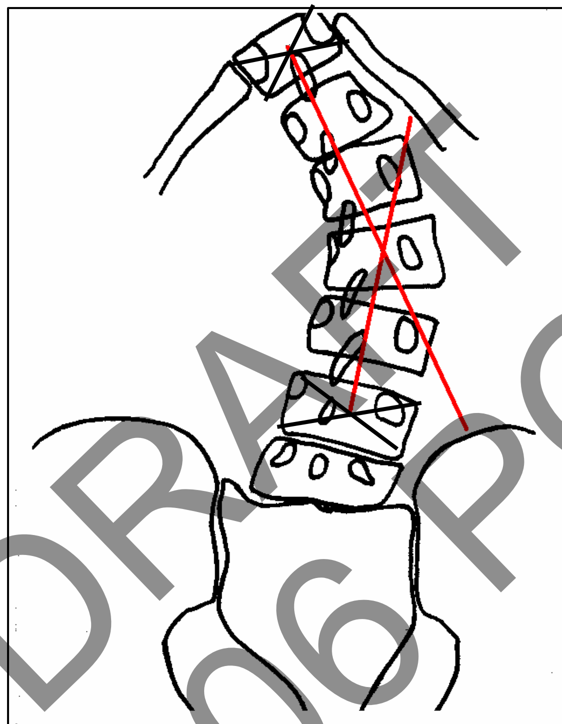

Figure 3: Risser-Ferguson Method of Scoliosis Measurement. The "centroid" or geometric center is found for the upper and lower end vertebra, as well as the apical vertebra. The "Risser-Ferguson" angle is measured from 2 intersecting lines constructed by connecting the apical centroid to the lower and upper centroids.

Risser-Ferguson Method: The Risser-Ferguson method (**See Figure 3**) is another means of quantifying scoliosis magnitude, but is reported much less in the literature. Stokes et al[20] suggested using the Risser-Ferguson method in situations where the Cobb angle measurement is technically difficult or non-representative. They[54] found a ratio of 1.35 to 1 for Cobb angles to Risser-Ferguson angles on AP radiographs (review Figure 2).[54] Similarly, Harrison et al[55] found a ratio of 1.6 to 1 when comparing the T12-L5 Cobb angles to Modified Risser-Ferguson angles.

Chiropractic Biophysics: Modified Risser-Ferguson Method: In 2 separate investigations, CBP technique evaluated the reliability of their method to evaluate spinal and sacral alignment from true vertical on the AP lumbar radiograph with line drawing methods.[16,40]

The 2-dimensional center of mass (2-DCOM) was determined and best-fit lines constructed forming a lumbodorsal (LD) angle in the mid lumbar spine. The resultant LD angle is measured in degrees. The angle of the sacral base relative to horizontal (HB) was evaluated.

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The angle of the distal "lumbar" line was measured relative to the sacral base superior endplate line resulting in the lumbosacral or LS angle. The final variable was the perpendicular distance of the T12 2-DCOM from a vertical axis line constructed from the center sacral tubercle (Tx^{T12}). Thirty seven radiographs were analyzed by 3 examiners two times each.[40] The methods demonstrated ICC values (assuming nested factors) representing good to excellent for all parameters measured. The repeated measures ANOVA resulted in ICC values of 0.71 for the HB angle, 0.97 for the LD angle, 0.83 for the LS angle and 0.95 for the Tx^{T12} linear distance.[40]

In a second analysis of the Modified Risser-Ferguson method with ICC's assuming random crossed factors, Harrison et al[16] showed that the same data actually produced higher reliability (greater than 0.88) for all measures except the measures of the sacral base (0.61-0.78).

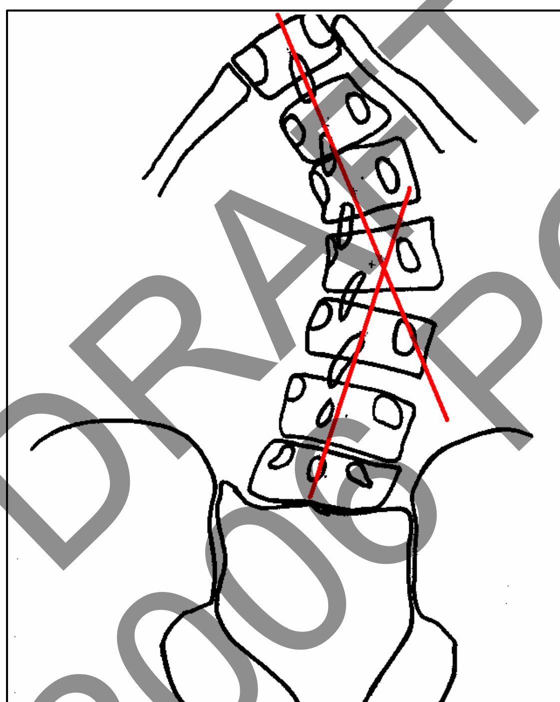

Figure 4: Modified Risser-Ferguson method. The "Harrison angle" is calculated by finding the projected center of mass of each vertebra and constructing 2 best-fit lines. This center of mass is located at the mid-posterior vertebral body. It is found on AP x-rays by bisecting the vertebral body from the side at the narrow waisted margins, then taking half way to the spinal laminar junction.

Reproducibility of Patient Positioning

Plaugher et al[30] in 1993, studied the repeatability of AP lumbopelvic radiographs taken 1 hour apart in one group and after 18 days in another. Paired t-tests were performed to observe differences between the two radiographs. They found that there was no statistically significant difference between the films for all measures performed.

In a 2005 study, Harrison, et al,[15] evaluated the test re-test reliability of AP lumbar radiographs in a control group comprised of 37 subjects who did not receive care. Initial

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radiographs were obtained and follow-up radiographs were taken an average 8.7 months later. The measurements on the two AP lumbar radiographs were essentially unchanged, including the HB angles, LD angles, LS angles and Tx^{T12} measurements. These measurement comparisons take into consideration the repositioning of the patient almost 9 months following the initial radiograph.

Pruijs et al[34] showed that when one examiner analyzed 3 serial radiographs of ten scoliosis patients, the variation of the Cobb angle was minimally affected (average of 2.2°, maximum of 7°) by the repositioning of the patient and the x-ray tube as seen on pre and post films obtained on the same patient one year apart. They state, "*Apparently, subjects with established spinal deformity assume a more or less similar position each time they are subjected to X-ray examination.*"[34]

The error due to repositioning is within the range of averages reported for the interexaminer reliability of the Cobb analysis on the same radiograph.[5,7,13,19,29] Therefore, the PCCRP panel considers the effects of repositioning to be negligible upon the measured magnitude of lumbar spine subluxations on AP/PA lumbar radiographs.

Diagnostic Capabilities

The AP lumbar view has been used to evaluate many anatomical structures visible on the film. The lumbar vertebra from T12-L5, sacrum, ilia, sacro-iliac joints, and distal ribs are generally visible on the radiograph. Soft tissue structures of the abdomen and pelvis are also evaluated diagnostically.

Validity

Multiple investigations have found correlation and predictive validity of the AP/PA Lumbar radiographic alignment to a variety of health related conditions. A review of these investigations is provided below. The AP/PA Lumbar view has the following correlations:

1. Cobb angle magnitude can predict scoliosis progression,[4,20,33,39,41,42,]
2. Initial apical vertebral rotation, lateral translation and L5 vertebral height relative to the iliac crest can predict adult AP lumbar curve progression,[33]
3. AP lumbar curve subluxation magnitude predicts flexibility and range of motion,[11,56]
4. Magnitude of AP lumbar subluxation/displacement correlates to rate of osteoarthritis,[33,35,41]
5. Magnitude of AP lumbar subluxation correlates to low back pain,[17,18,22,23,38]
6. Magnitude of AP lumbar subluxation correlates to Health Status Scores.[37]

Cobb Method

The magnitude of scoliosis as determined by the Cobb angle on plain films has been shown to be predictive of progression of the curve. In a study of 85, 627 children screened for scoliosis it was shown that, for those with scoliotic curves > 30°, the incidence of progression (increasing Cobb angle > 5° from visit to visit) was 48%. For curves 10-20° the rate was lower at 11.9% to 20 % respectively.[39] Pritchett, et al,[33] investigated risk factors for curve progression in patients over the age of 50 with adult onset degenerative symptomatic scoliosis. He found that patients progressed at an average of 3º per year in 73% of the subjects over the 5-year study. The authors state, "Grade 3 apical vertebral rotation, a Cobb angle of 30° or more, lateral vertebral

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translation of 6 mm or more, and prominence of L5 in relation to the inter-crest line were important factors in predicting curve progression".

Magnitude of the lumbar curve patterns in adolescents with idiopathic scoliosis has been studied extensively to estimate a progression threshold magnitude. In 40-year[42] and 50-year[41] follow-up studies, Weinstein et al demonstrated that lumbar curves exceeding 30º Cobb angles at skeletal maturity were at high risk for continued progression. Apical vertebral rotation greater than 33% was present in all frontal plane curves larger than 30º. MacGibbon and Farfan[20] and Ascani[4] found similar results with regard to a 30º threshold for progression of lumbar curves of adolescent idiopathic onset. Idiopathic thoraco-lumbar curve patterns were shown to possess the most apical vertebral rotation. This increased rotation and the presence of lateral vertebral translations are indicative of progression.

The magnitude of the curve also has an inverse relationship to the degree of flexibility and coupled motions as measured on lateral bending radiographs.[11,56]

Abnormal spinal displacement analysis of the lumbar spine resulting in scoliosis has been associated with low back pain. Jackson et al[17] showed that the incidence of low back pain in a group of adult patients with idiopathic scoliosis was the same as an age-matched control group. However, the pain was much more severe in the group with scoliosis. Pain increased with age and Cobb angle magnitude ($P < .0005$). Kostuik et al[18] found that in adults with scoliosis, there was a direct relationship between the magnitude of the Cobb angle and the severity of low back pain, particularly for curves over 45°. Schwab et al[22] (2005) did not come to the same conclusion. However, the magnitude of the scoliosis in his subject groups was smaller. In a 1994 study,[23] it was shown through retrospective analysis that scoliosis subjects had higher prevalence of low back pain than a matched group with a similar phone administered survey. Subjects were adults with adolescent onset idiopathic scoliosis. The pain in those with demonstrable Cobb angles on previous films described their pain as more continuous, generalized, intense and radiating into the extremities. They were also more restricted in their usual daily activities. Schwab et al,[38] in 2002, were able to establish predictive validity of radiological parameters, including vertebral latero-listhesis and L3 and L4 endplate obliquity angles, for self-reported pain levels.

Richter et al,[35] studied the rate of osteoarthritis in a group of 100 scoliosis patients with an average age of 19 years and ranging from 12-30 years old. Therefore, this group did not include anyone with so-called "age-related" osteoarthritis of the spine. The authors found that, "37% of curves less than 20° had osteophytes, and this increased to 53% of curves greater than 40°."[35] Subjects were compared to a control group and were found to have a higher incidence of degenerative changes ($P < .01$). Two observers graded the degenerative changes and there was a close inter-observer correlation. In addition, ten of the films were repeated without knowledge of previous assessment by both observers demonstrating good intra-observer reliability. One study demonstrated that in 73% of subjects over the age of 50 with degenerative symptomatic lumbar scoliosis, curves progress at an average rate of 3° per year over a 5 year period.[33] The average initial Cobb angle was 30º, there was significant axial rotation of the apical vertebrae, and a latero-listhesis > 6 mm. All measurements were taken on frontal plane films. In a 50-year follow-up study of untreated adolescent idiopathic scoliosis, individuals demonstrated significant spinal degeneration, with radiographically measured, latero-listhesis being a common indicator of low back pain.[41]

Misalignment of the lumbar spine in scoliosis patients, as measured by the Cobb angle, has also been associated with different Health-Related Quality of Life (HRQL) parameters.

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Schwab et al,[37] in their 2005 study, showed no correlation between an elderly population with scoliosis and visual analog pain scale. However, those patients with scoliosis Cobb angles 10-20° had lower scores for Vitality ($P<0.05$) and Mental Health ($P< 0.02$) as compared to U.S. population norm (age 65-74 age group).

Biomechanical Validity:

For this type of validity, the clinician compares the spinal coupled motions on the AP Lumbar radiograph to the published results of "main motion coupled motion" performed on thoraco-lumbar postural movements. If the usual coupled motion patterns on AP lumbar radiographs are not present for a particular thoraco-lumbar posture, the clinician is alerted to the fact that either anomalies or spinal injuries are present.

Several main motion/coupled motion investigations have been reported for thoraco-lumbar movements and AP Lumbar radiographic patterns.[55,57]

It is the consensus of the PCCRP panel that the quality of investigations finding a correlation between AP lumbar radiographic alignment and the conditions in the above 6 categories is scientifically sound. Thus, we conclude that the AP lumbar radiographic alignment has positive correlation and validity for these 6 categories.

Outcome Investigations

Level I Studies: No Level I studies utilizing chiropractic intervention could be located.

Level II Studies:

In a non-randomized clinical controlled trial, Harrison et al[15] reported on 63 patients with chronic low back pain matched to a control group with the same condition. Patients were treated with CBP methods directed at subluxation correction of the spine in the frontal plane. Radiographs were taken initially and at final evaluation. The patients demonstrated approximately 50% structural alignment of trunk list (Tx^{T12}), as well as approximately 40% improvement of the LD angle and LS angles. These improvements in structural alignment were associated with improvement in self reported Numerical Rating Scale (NRS) pain level (initial avg. = 3.0, post care = 0.8). The control group did not demonstrate statistically significant change in any of the AP lumbar radiographic measurements (except a slight worsening of the Tx^{T12}) nor in NRS levels.

Level III Studies: No Level III studies using Chiropractic intervention could be located.

Level IV Studies:

Many well reported cases of chiropractic management of AP lumbar subluxations, including lumbar scoliosis, have been described.[1-3,6,9,14,21,22,27,28,32,58-64] The treatment employed in these cases was almost always dictated by the appearance of the scoliosis on the frontal plane image. The primary outcome measure is the Cobb angle as measured manually on the x-ray, and pain and disability scores. Several examples of these studies follow.

In a 2004 case report, Alcantara et al[3] reported on chiropractic treatment of a 23-year old male patient with low back pain associated with subluxations and a malgaigne-type fracture of the pelvis. The authors utilized Gonstead method of analysis and treatment, including

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radiographic line drawing analysis of segmental subluxation misalignment. The patient was seen only 5 weeks following the acute fracture of the pelvis. Subluxations were treated at spinal levels of L2 and L5, as well as the left ilium. The patient was cared for daily for 2 ½ months. Initial follow-up radiographs were obtained at 1 month demonstrating improvement/correction of the subluxation listings. His pain was significantly reduced and he was able to return to work as a dry cleaner. The patient was seen periodically for the following 13 years.

Alcantara et al[2] report on a 2-year old girl who presented with her mother for symptoms associated with recent onset myasthenia gravis following a motor vehicle collision. Adjustments were provided to the cervical and sacral spines based in part upon specific spinal listings measured form AP images of the spine. The toddler responded well to care and was free of symptoms following 5 months of care. For the first 3 ½ months of care the girl was adjusted 2-3 times a week. Comparative x-rays were taken and evaluated with reported improvement.

Alcantara et al[1] also described similar results in a patient with subluxation, low back pain and epileptic seizures.

Berry et al[58] reported on the successful management of a patient suffering from low back pain and leg pains with disc herniations. The patient was previously treated with surgical decompression including a laminectomy and was unresponsive to traditional chiropractic manipulation. The patient was treated with CBP methods to correct spinal subluxations of the AP lumbar radiographic view, lateral cervical view, and the head-thorax and thoraco-lumbar abnormal postures. Following 9 months of Chiropractic rehabilitative care with multiple re-examinations the patient's disability score on the Oswestry Chronic Low Back Pain Disability Questionnaire indicated that the patient improved during treatment from 74% to 24%; while spinal and postural subluxations were corrected to near normal limits.

In a retrospective case series, Harrison et al[59] reported on the reductions of thoraco-lumbar scoliosis in five patients using the Chiropractic Biophysics treatment methods. Thoraco-lumbar scoliosis was significantly reduced in all patients as were NRS and Oswestry disability scores. Significantly 4/5 subjects had long-term follow-up showing stability of the AP lumbar radiographic subluxation reductions.

Colloca and Polkinghom[9] reported on two patients with Ehlers-Danlos syndrome who sought chiropractic care for disabling musculoskeletal pain. The patients were treated according to Activator Methods Chiropractic Technique and Chiropractic Biophysics methods. In one patient (43-year old male) the self-reported pain and disability improved and upon repeated radiographic examination, lumbar Cobb angle improved from 5° to zero. The anatomical leg length inequality improved from 12 mm to zero as well.

Morningstar and Joy[27] described the treatment of scoliosis in 3 cases using Pettibon body weighting system. AP radiographs were obtained and measured Cobb angles were reported (35°, 22° and 37°). Treatment consisted of manipulation and exercises. Home care was a major component of the treatment. Curve direction as measured on the AP films dictated course of care. Post treatment radiographs were obtained. Cobb angles reduced to 13°, 8° and 16°, respectively.

Morningstar[28] also reported on the effectiveness of their methods in a case series of 19 subjects with scoliosis. Pre-treatment radiographs were taken on each patient and Cobb angles were measured. Post-treatment radiographs were taken 4-6 weeks following their intervention and comparative Cobb angles were constructed. There was an average 17° reduction in the Cobb angle.

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Adjunctive Procedures:

In a recent survey of the intention of chiropractors to manage adolescent idiopathic scoliosis, 86% of responding chiropractors reported that would utilize exercises in their treatment plan.[12] In our review of the literature, we found many studies investigating the effectiveness of exercises alone, and in combination with other procedures, in the management of lumbar scoliosis.

Mooney and Brigham[26] found that scoliotic patients had asymmetrical axial rotational strength of the thorax, which occurs at the Thoracolumbar junction. Ten out of 12 subjects had weakness of the muscles on the concave side of the curve. They conducted a 4-month strength-training program using Med-X strength training equipment. Sixteen of the 20 subjects demonstrated curve reduction.

Miyasaki[25] studied the effect of their thoracic flexion exercise on apical rotation and the lateral flexion deformity on patients while they are in the Milwaukee brace. They found that the thoracic flexion exercise significantly reduced the deformity as compared to standing passively in the Milwaukee brace with no exercise. Manually constructed Cobb angles were used for evaluation of the curve magnitude. If the curve pattern resulted in a “decompensation” of the spine, as is commonly seen on AP radiographs in patterns involving the thoracolumbar or lumbar spine, then Miyasaki[25] recommended lateral shifting of the trunk with respect to the pelvis while in the brace. The shift is performed toward the thoracolumbar or lumbar curve convexity, without regard to the presenting posture of the patient. This particular procedure was recommended mainly for primary lumbar curves, for this is where the action of the maneuver occurs.

Mehta was the first to report the use of lateral shifting exercises as a primary intervention in the correction of scoliosis.[24] She[24] recommend using a mirror so the patient can see the mirror image of the lateral shifting. She reported that her results “indicate that they are comparable with those reported by braces or electrospinal stimulation”.[24] The patients had an initial Cobb angle between 15º and 42º. The post treatment Cobb angle had either decreased or remained unchanged in 71% of the patients. Over the course of 1.9 years, the group considered “most at risk” for progression averaged only 2.0º increase of curvature. Although this may not sound satisfactory, remember that for a curve to be considered progressive it must increase in severity by 5º or more in one year. Therefore, the most at risk group which was most likely progressive only worsened by 2º versus the 10° expected during the “watchful waiting” period recommended by many medical authorities. Mehta states, “thoracolumbar and low thoracic curves respond best to the side-shift, lumbar curves less so, particularly when there is an acute take-off at L5”.[24]

Another recent study by den Boer et al, in 1999,[10] demonstrated that active “side-shift” exercises were found to have a promising effect on Cobb angle in idiopathic scoliosis patients with an initial Cobb angle ranging from 20-32°, ages 10-15 and in those who performed the therapy for more than 4 months. The patients participated in 10-12 half-hour sessions once a week to learn the side-shift procedure. Patients were instructed to perform the shift as often as possible each day. They received a refresher course once a month. The side-shifting group showed only a 2° increase of Cobb angle after 4 months. They compared these results to a matched historical brace cohort group, which showed a 2° decrease in Cobb angle. Also of importance is the non-compliance of each group. The side-shift group only had 4.5% non-compliance, while the brace group had resulted in 24.2% of the original group not in compliance. This demonstrates the tendency for the adolescent aged patient’s preference for non-bracing treatment.

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German clinical researcher Hans Rudolf Weiss reported success utilizing a 3-dimensional exercise program in the reduction of scoliosis. In one study, published in 1992,[48] he reports on the effectiveness of the program on 107 patients. Exercises designed to reduce the curves were used (called "rotational breathing"). The average Cobb angle of the primary curve decreased from 43° to 40° and the secondary curve decreased from 28° to 26°. Greater than 97% of the primary curves and over 99% of the secondary curves either decreased in magnitude or remained the same. The group in this study was relatively mature, average age =21.6 years, and thus at a lower risk for progression. To test whether positive results could be obtained for patients considered at high risk for progression, in 1997, the same group studied 181 patients with an average chronological age of 12.7 years, average Cobb angle of 27° and average Risser sign of 1.4.[44] By current knowledge, this represents a high-risk group. They used the same exercise program as in the 1992 study and performed a follow-up at an average of 33 months. The group as a whole (N=181) demonstrated an initial Cobb angle of 27° and at 33-month follow-up it measured 29°.

Similarly, in 2003, Weiss et al[47] performed an age, sex and curve magnitude matched, controlled clinical trial, which demonstrated that their methods reduce the incidence of progression in children with idiopathic scoliosis. This group has reported similar successful scoliosis intervention in several other clinical studies.[43,45-47]

Summary

A systematic review of the literature reveals that frontal plane imaging of the lumbar spine, in either the anteroposterior (AP) or posteroanterior (PA) directions is a common diagnostic procedure in the medical, chiropractic and physiotherapy professions. Radiographic line drawing procedures used for spinal displacement analysis is also common in all professions. Line drawing methods are widely used for scoliosis assessment, that is, global or regional subluxation, as well as for determination of intersegmental subluxation by Chiropractic clinicians. Repositioning patients while producing frontal plane lumbar radiographs is repeatable. The biomechanical information obtained from these radiographs is reliable and valid and is used in the determination of care in chiropractic, physiotherapeutic and medical settings.

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13. Lateral Lumbo-pelvic Radiographic View

RECOMMENDATION

The Lateral Lumbo-pelvic Radiographic view is indicated for the routine quantitative assessment of the biomechanical components of vertebral subluxation. This radiographic view has reliability, validity and clinical outcomes data that evidence its clinical utility in clinical chiropractic practice. When using this radiographic view, a baseline value of the biomechanical component of spinal subluxation should be determined prior to the initiation of chiropractic treatment intervention. In this manner, response to care can be determined.

Supporting Evidence: Clinical Levels II, III, IV,V, Reliability Studies Class 1 and 2, Population Studies Class 1 and 2, Biomechanics, and Validity.

PCCRP Evidence Grade: Clinical Studies = B, C, D.

Introduction

In radiography of the lumbar spine, the first to be obtained is generally the lateral lumbo-pelvic view. Care should be taken to insure that several structures are visible from the lower thoracic spine superiorly to the tops of the femur heads inferiorly. In many cases, a lateral lower lung field filter is needed in order to adequately visualize the entire lumbar spine.

In chiropractic analysis, the lateral lumbar should be taken in the upright standing position at the standard tube distance of 100 cm (40 inches) with the central ray located approximately at the L3-L4 disc level. For lateral lumbo-pelvic radiographs, the patient's arms are positioned out of the field of x-ray view by placing the hands on a rest at iliac crest height[1], by folding the hands on top of the head,[2] or by folding the arms on the chest placing the hands in the clavicular fossae.[3]

Since chiropractic clinicians are interested in the alignment of the patient's individual spine, the self balance position seems appropriate to ascertain the patient's unique subluxation alignment. The patient's abnormal sagittal plane posture is left as is, i.e. it is not guided towards an ideal neutral position. Figure 1 depicts the 'self balance positioning' of a patient with hands on a rest at iliac height, hands on top of the head, and with hands in the clavicular fossae in their neutral resting posture.

Reliability of Measurement Methods

The lateral lumbo-pelvic radiograph measurements include the sacral base to horizontal, sagittal translation or balance, pelvic tilt, pelvic morphology, segmental sagittal plane translation for retrolisthesis and anterolisthesis, segmental rotational lordosis, and global lordosis measures. These variables have been measured in a multitude of different ways on lateral lumbo-pelvic radiographs. The Harrison Posterior Tangent, Cobb, Centroid, Trall, and Pelvic Radius have all been subjected to examiner reliability investigations.[4-16]

Harrison et al[4] and Troyanovich et al[5] investigated the inter- and intra-examiner reliability of the Harrison Posterior Tangent (HPT) method for assessment of lumbar lordosis. Excellent examiner reliability, low standard errors of measurement, and small absolute differences of observers' measurements were found. See Figure 2.

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Harrison et al[4], Polly et al[6], Chernukha et al[7] have investigated the reliability of the Cobb Method for measurement of lumbar lordosis.[4,6,7] Here, the superior or inferior endplates of the vertebra is used to construct lines. See Figure 3.

Figure 1 AB. Self balance position for the lateral lumbo-pelvic radiograph. In A, the patient assumes their neutral postural balance and then the arms are bent at the elbow and shoulder approximately 135° and the hands are placed on a rest at iliac crest height. In B, the arms are abducted, elbows flexed, and hands folded on the head. In C, the patient assumes the 'self balance position' and then the arms are folded on the chest placing the hands in the clavicular fossae.

The Centroid Method for measurement of lumbar lordosis has been studied in two separate reports and found to have excellent examiner reliability.[4,8] Figure not shown

The tangential radiologic assessment of lumbar lordosis (TRALL) uses an apex at the greatest depth of lordosis.[4,7] This methods has been found to have excellent inter and intra-examiner reliability.

The Pelvic Radius Technique for measuring lumbo-pelvic alignment. This method depends upon construction of the pelvic radius (PR) and has been found to have excellent inter and intra-examiner reliability.[9,10] Figure not shown.

Collectively these studies indicate that measurement of the lateral lumbo-pelvic radiographic alignment has excellent observer reliability for a variety of methodologies.[4-16]

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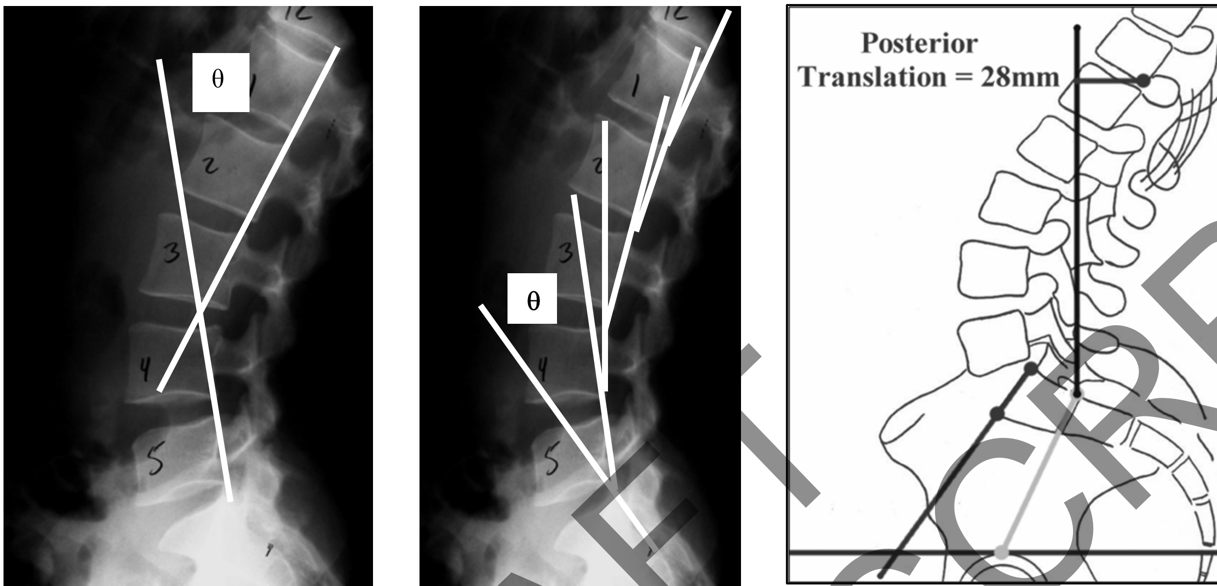

Figure 2. The Harrison Posterior Tangent (HPT) method. In A, HPT lines are drawn along the posterior body margins of L1-L5 to measure the magnitude of the curve. In B, HPT lines are drawn along the posterior body margins of all segmental levels, T12-S1, in order to measure segmental angles termed relative rotation angles (RRA's). In C, the sacral base to horizontal, pelvic tilt, and sagittal translation balance are shown. The HPT method for measuring lumbar lordosis has high reliability, low standard errors of measurement, and small absolute differences of observers' measurements.[4,5]

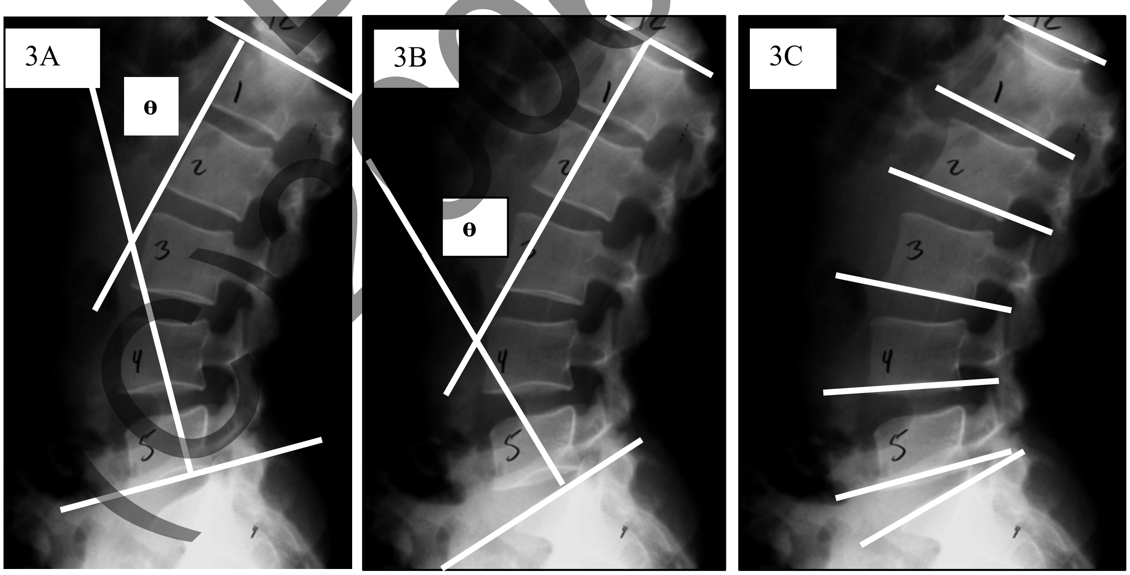

Figure 3. The Cobb Method can be drawn with 4-lines or 2-lines and from a variety of different levels. In A, the 4-line Cobb angle from superior endplate of L1 and the inferior endplate of L5. In B, the 2-line Cobb angle from the inferior endplate of T12 to the superior sacral endplate of S1. In C, segmental Cobb angles constructed with lines drawn on the inferior endplates of T12 through L5 and the superior sacral base. These methods have good to excellent examiner reliability.[4,6,7]

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Repeatability of Patient Positioning

At least four studies have performed repeat radiographs of the lateral lumbar spine in the same subject.[1,10,12,17] Without exception, these four investigations clearly demonstrate that lateral lumbo-pelvic alignment on repeated radiographs is repeatable even when films were taken by different examiners months or years apart.

For example, Jackson et al[10] reported ranked correlation coefficients of 0.93-0.96 for lumbar lordotic measurements for initial and follow-up x-rays of 20 volunteers and 20 low back pain patients. Harrison et al[17] analyzed initial and repeat lateral lumbar x-rays in 30 control group subjects where follow-up x-rays were collected after a mean of 9 months. All angles and distances changed less than 1° or 1 mm and all P-values were not statistically significantly different (P>0.05). Stagnara et al[1] stated, "*For subjects undergoing clinical and X-ray examinations at intervals of five to ten years, and where no growth or pathologic deformation factors are to be taken into to account, the clinical and X-ray measurements of kyphosis and lordosis are remarkably constant to within a few degrees, provided the position is clearly stipulated.*"

Saraste et al[12] investigated the differences between radiographs of 125 spondylolytic patients in the recumbent and standing positions with respect to vertebral slipping and lumbo-sacral lordosis. There were only minor projectional and interobserver measurement errors in the variables describing vertebral size and lumbosacral lordosis, which make these variables suitable for radiographic assessment at repeated examination.

Diagnostic Capabilities

When properly performed, lateral lumbo-pelvic radiograph will provide visualization of several structures, subluxation abnormalities, anomalies, and pathologies. The vertebral bodies, disc spaces, articular pillars, spinous processes, sacrum, and femur head/acetabular landmarks should all be visualized. The lateral lumbo-pelvic view provides the chiropractic clinician with valuable information including:

1. Total lumbar lordosis,
2. Segmental lumbar lordosis,
3. Breaks in Georges' line or sagittal plane translation of the posterior vertebra and spinous lamina junction for a general stability analysis,
4. Sacral base angle to horizontal,
5. Pelvic tilt,
6. Pelvic morphology,
7. General translation alignment of the ribcage relative to the pelvis,
8. Stages of disc, ligament & vertebral body degenerative pathologies,
9. Stage of articular process degeneration,
10. Spinal canal dimensions,
11. A number of other anomalies, fractures, and instabilities.

Validity

Multiple investigations have been performed, finding correlation and predictive validity of the lateral lumbo-pelvic radiographic alignment to a variety of health related conditions including:

1. acute and chronic low back pain,[9,10,18-34,67-70]
2. health quality of life and disability measures,[30-33]

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3. sick leave and 1st time occurrence of low back pain,[33,34]
4. stress/strain relationships & degenerative joint disease (DJD),[35-42]
5. sciatica and radiculopathy,[43]
6. spondylo-listhesis development, pain, & progression,[44-49]
7. range of motion and segmental motion patterns,[50,51]
8. post surgical patient pain and disability outcomes,[52,53,72]
9. risk of deformity progression,[54-56]
10. hip osteo-arthritis,[70,71] and
11. post-surgical hardware failure.[73]

Oppositely, a few investigations have found that the lateral lumbo-pelvic alignment measurements do not correlate to and predict the findings in the above 11 categories.[57-63] However, many of these investigations have been found to be internally flawed and critiques of these studies has been performed.[64-66] It is the consensus of this panel that the number and quality of investigations finding a correlation between lateral lumbo-pelvic radiographic alignment and the conditions in the above 11 categories is superior to the few negative correlation studies. Thus, we conclude that the lateral lumbo-pelvic radiographic alignment has positive correlation and predictive validity for the 11 categories.[9,10,18-56,67-73]

Outcome Investigations

Several outcome investigations have been performed using a variety of chiropractic procedures aimed at restoration of the lumbar lordosis and improvement in the sagittal lumbar alignment in a variety of patient pain and health disorders.[17,74-79] In at least 2 investigations no improvement in lumbar lordosis was found following chiropractic adjustment procedures.[79,80] However, 1 study[79] found reductions of the retrolisthesis subluxation of the lumbar vertebra and neither study utilized a multi-modal approach.[79,80]

Level I Studies: No Level I studies could be found.

Level II Studies:

In a non-randomized clinical control trial adding the chiropractic procedure of extension traction to traditional chiropractic lumbar spine adjustment methods, Harrison et al[17,74] found consistent increases in lumbar lordosis and reductions in chronic pain intensity in treated patients with chronic low back pain compared to no changes in a control group. Importantly, at 1.5 year follow-up, the pain and subluxation improvements were stable in the treatment group.

Level III Studies:

Even though no change in lumbar lordosis was found following Gonstead adjustments to the lumbar spine, the study by Plaugher et al[79] identified a measurable improvement in segmental retro-listhesis at follow-up lumbar radiography.

Level IV Studies:

In a case series of 3 males with degenerative flat back syndrome (kyphotic lumbar spine with anterior sagittal balance), Harrison and Bula[75] found that a combined chiropractic approach using lumbar adjustments and extension traction improved the lumbar lordosis and decreased pain and disability.

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Paulk et al[76] presented a case report of failed conservative management of low back pain, leg pains and impairments due to disc herniations and loss of lordosis. Following Chiropractic Biophysics adjustments and lumbar extension traction, the pain and impairments improved and the lumbar lordosis was re-established to near normal alignment.

In a modified version of the supine 3-point bending lumbar traction unit developed by Harrison et al[17,74-76], Troyanovich and Buettner[77] reported an improvement in lumbar lordosis in a patient with D.I.S.H.

Morningstar et al[78] reported on the successful management of thoracic pain and impairment due to lumbar kyphosis and anterior head translation. Re-establishment of the lumbar lordosis was found utilizing Pettibon technique procedures.

Collectively, these reports[17,74-79] indicate that patients benefit from combined (multi-modal) chiropractic technique interventions aimed at improvement and/or restoration of an abnormal lateral lumbo-pelvic spinal alignment.

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14. Lumbar Flexion and Extension Radiographic Views

RECOMMENDATION

The Lateral Lumbar Flexion/Extension Radiographic view is indicated for the quantitative assessment of the biomechanical components of vertebral subluxation. These views should be obtained when a patient has suspected instability, sustained lumbar trauma, pain upon sagittal plane movement, and/or for kinematic evaluation. This radiographic view has reliability, validity, biomechanics and clinical outcomes data that evidence its clinical utility in clinical chiropractic practice. When using this radiographic view a baseline value of the biomechanical component of spinal subluxation should be determined prior to the initiation of chiropractic treatment intervention. In this manner, response to care can be determined.

Supporting Evidence: Clinical Levels III and V, Reliability Studies Class 1 and 2, Population Studies Class 2, Biomechanics, and Validity.

PCCRP Evidence Grade: Clinical Studies = C, D and Reliability, Biomechanics and Validity Studies = a.

Introduction

The lateral flexion and extension studies represent a means to acquire more in-depth analysis of lumbar spine function and pathology, especially of hypo- and hyper-mobile segments. Hyper-mobile being an increase in segmental rotation angles about the horizontal axis and/or an increase in AP or PA segmental translations. These views are typically done immediately following a neutral lateral and AP views, or can be done as follow up views to aid in further analysis and patient care, essentially for segmental instability. The lumbar flexion-extension views are often termed "dynamic views" but, in fact, are end-range static stress x-rays. (See Figure 1) These views have been done in the sitting or standing positions.

Flexion-extension studies may also be used for pre and post-treatment evaluation; i.e. an improvement in the global/segmental range of motion or an improvement in the dynamic function of the back. Evaluation of segmental translations and rotation angles in the A-P or P-A directions have been evaluated by a variety of ways.[4,14,18,23,25,29,31]

Flexion-extension views are taken with the tube and grid cabinet distance at 72 inches. The central ray is adjusted vertically to approximately 1-2 inches below the top of the iliac crest (level of L3). The grid cabinet, or bucky, is vertically positioned to accommodate the central ray. Many different measurements have been described over the years by both chiropractors and medical physicians to evaluate the biomechanical movements of T12, L1, L2, L3, L4, L5 and the sacrum/pelvis on these flexion and extension radiographs. We will review some common methods and measurements. Additionally, we discuss the reliability, validity, and outcome assessment studies.

Reliability of Measurement Method

Flexion-extension X-rays, with maximal extension and flexion of the lumbar tract, represents the most widely used technique and a reliable and valid method to estimate sagittal segmental lumbar motion.[3] In essence, the exact same measurement methods as used on the neutral lateral lumbar x-ray are used and thus the same reliability studies apply (See view #13 above).

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There are two methods of measuring lumbar lordosis that have been carried over to flexion-extension measurements in the lumbar spine, end plate analysis and posterior tangent analysis.[2,9] In 2001, Harrison et al[9] reported that the Cobb method and the Harrison Posterior tangent method were highly reliable and had the ability to create and measure segmental angles of rotation.

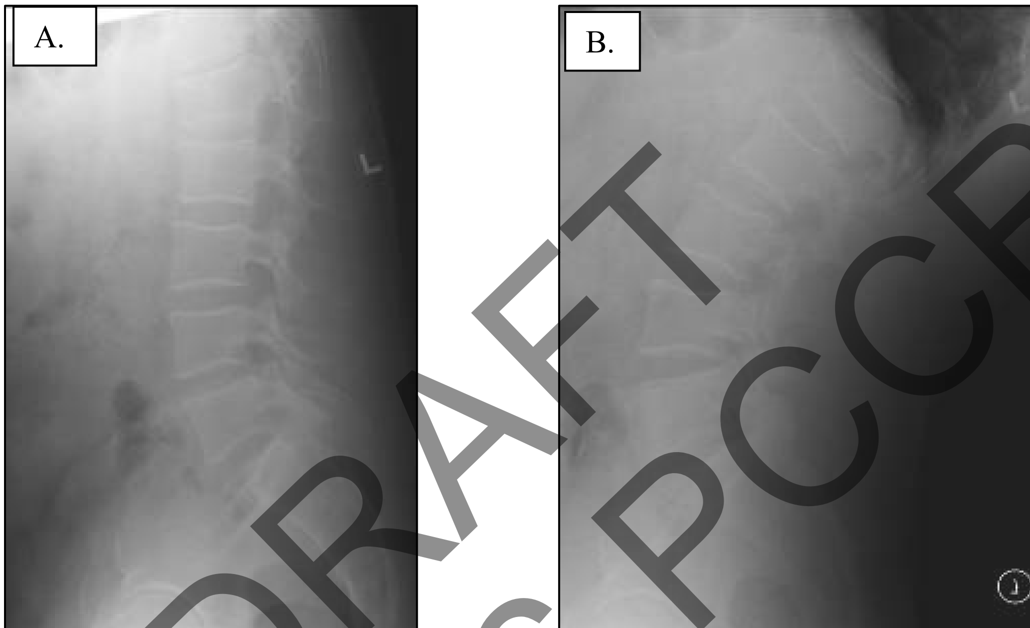

Figure 1. **Lateral Lumbar Flexion and Extension Radiographs.** The patient is positioned with the pelvis centered to the bucky. The central ray is aimed at the L3 level. The 14x17 cassette may have to be rotated 90° in order to have T12 appear on the film in flexible persons. In A, lumbar flexion is shown. In B, lumbar extension is shown. Note: the L1 compression fracture and the retrolisthesis apparent at L1 and slightly at L2.

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However, the usual method of measuring segmental lumbar spine rotation mobility is by comparing posterior tangents. Using hand superimposition of the same segment on lumbar spine radiographs in flexion and extension (e.g., L5), one compares the posterior tangents at the posterior vertebral body margin for the vertebra immediately above (e.g., L4) for a segmental angle of total flexion-extension. Often this method lacks precision due to differences in the cortical outline of the vertebral bodies in flexed and extended positions. The introduction of digitizing vertebral margins on radiographs and digital image processing have created the possibility of computerized superimposition ('matching') of digital vertebral body images by means of image registration.

In 1990, Putto and Tallroth[24] studied reliability of two methods of measuring segmental motion on flexion-extension films. Their new examination method yielded better mobility of the spine than any method earlier described. For the two lowest vertebral spaces, L4-5 and L5-S1, the new method implied significantly greater angular mobility and total angular mobility between L2-S1 than a previous method. Intra- and interobserver errors accounted for were acceptable and the accuracy of the measurements sufficient for clinical work.

In 1991, Dvorak et al[6] reported normal angles of rotation for 41 healthy adults in passive motions. A graphic construction and a computer-assisted method were used to measure lumbar segmental rotations. The graphic construction and the computer-assisted methods were found to be equally reliable, but the computer method could also yield measurements of translations.

In a 1992 study, Panjabi et al[20] determined errors in motion parameters due to spinal level, radiographic quality, and errors in performing measurements with two digitizing instruments. The error (2 x SD) ranges were (1) ±1.25° for rotations, (2) ±0.86° for translation of the inferior posterior body corner, and (3) ± 4.3 mm for the coordinates of the center of motion. They stated that both the spinal level and the radiographic quality affected the magnitude of errors in all motion parameters.

In 1994, Tallroth et al[27] studied the reliability of extension-flexion radiography by analysing intra-observer and inter-observer variations in measurements of 30 patients with established L5-S1 spondylolisthesis. The overall consistency and concordance were good. The variations in intra-observer and inter-observer readings were similar.

In 2005, Penning et al[21] reported on a computerized method on digital radiographic images. To check accuracy and convenience of the new method, two computer program experts performed five image registration measurements of the five lumbar motion segments in five consecutive flexion-extension studies. Pathologies observed on these studies were old lumbar fracture, spondylolytic spondylolisthesis and degenerative anterolisthesis. "For comparison an experienced radiologist performed the same repeated measurements with the manual superimposition method. Measurement error of the image registration method proved to be significantly smaller than that of the manual superimposition method. The image registration method proved to be more convenient because the whole procedure from import of the image data to display of the measurement outcomes lasted 2-3 min compared to 3-6 min for the superimposition method."[21]

In 2005, Fritz et al[8] studied 49 subjects who had flexion-extension lumbar radiographs and who had low back pain. Repeatability of radiographic variables was reported to be high and 28 subjects had radiographic instabilities, while reliability of clinical variables ranged from moderate to good.

Reliability of Patient Positioning

Bronfort and Jochumsen[1] determined that least variation in measuring motion in the lumbar spine via flexion-extension views was the sagittal plane standing position.

Diagnostic Capabilities

The lumbar flexion-extension stress films are useful in determining the following biomechanical information:

1. Antero-listhesis and retro-listheses (instability),
2. Lumbar Kinematics at sagittal end range position,
3. Hypo/hyper-mobility or segmental articular fixations,
4. Evidence of instability,
5. Rotational instability.

Validity

Several attempts have been made to measure segmental range of motion in the lumbar spine during flexion-extension in order to gather data for the diagnosis of instability.

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In 1989, Hayes et al[10] obtained flexion-extension lumbar views in 59 asymptomatic individuals undergoing routine pre-employment examination. Results indicate that there is 7 to 14 degrees of angulatory motion present in the lumbar spine but a large range of values exist so that norms of angulatory motion cannot be more precisely defined. There are 2 to 3 mm of translational motion present in the lumbar spine at each intervertebral level. Twenty percent of this study's asymptomatic subjects had 4 mm or more translational motion at the L4-5 interspace and at least 10% had 3 mm or greater motion at all levels except L5-S1.

In 1991, Dvorak et al[5] attempted to determine the clinical validity of segmental measurements on lumbar flexion-extension radiographs for identifying the need for surgical intervention. In 101 adults, divided into 5 classifications of pathologies and physical conditions, it was found that all of the patient groups exhibited significant hypo-mobility, spread equally among all lumbar levels, in comparison to normal group motions.[3] Athletes were found to have hyper-mobility. Using segmental motion on the flexion-extension radiographs, they could not discriminate between the patient groups.[6]

In 1993, Lin et al[15] reported on lateral functional radiographs of flexion and extension using Putto's method in 89 normal subjects. For translation changes, 2 mm is regarded as acceptable in most cases at levels from L1 to L5, but not at the level of L5-S1 where the average translation change was only 0.4 mm. The differences in the absolute translation value among different positions were not statistically significant ($p = 0.064$).

In 1994, Lin et al[16] measured segmental motion in 89 subjects. From extension to flexion, all of the intervertebral rotations approached 0 degrees (straight spine in flexion) relative to the lordotic position; the translations changed from slightly retro-listhetic to zero displacement. Using L3-L4 as a baseline for calculating the intervertebral differences in flexion, all of the rotational differences were less than 1.5 degrees, except at L5-S1, which remained 5 degrees. The mean translational difference was less than 0.6 mm, except at L5-S1, where it remained 1.5 mm.

In 1994, Cardin[34] (a chiropractor) evaluated the active lumbar flexion-extension **radiographs** of low back pain patients and asymptomatic volunteers. The **radiographs** were evaluated to assess differences between the two groups using intersegmental angular and translational measurements. Average differences for angular and translational ranges of motion between groups were found, with a lower range of motion affecting the low back pain group. Subjective definitions of hypo and hypermobility were also offered to evaluate their prevalence within the samples.

In 1996, Inufusa et al[12] studied the canal and IVF diameters in flexion-extension. They reported that sagittal computed tomography scans showed that extension decreased all the foraminal dimensions significantly, whereas flexion increased all the foraminal dimensions significantly. The translational changes were associated with the bulging of the disc and the presence of traction spurs.

In 1996 using flexion-extension in 3 subjects, Fennell et al[7] reported that flexion of an intervertebral disc tends to be accompanied by posteriorly directed migration of the nucleus pulposus within the disc. Extension tends to be accompanied by an anteriorly directed migration.

In 1998, Zander and Lander[33] reported that in 10 of the 33 patients (12 levels), the CT myelogram underestimated spinal stenosis, as compared with the upright flexion-extension myelogram. In 5 levels, stenosis of 70% or more seen on flexion-extension myelography was measured as 50% or less on CT myelography.

In 1998, Wildermuth et al[30] reported that, in 30 patients, quantitative assessment of

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sagittal dural sac diameters is comparable between lumbar myelography and positional MR imaging. In a selected patient population, only small changes in the sagittal diameter of the dural sac and foraminal size can be expected between various body positions, and the information gained in addition to that from standard MR imaging is limited [corrected].

In 2000, Miyasaka et al[17] studied 90 adults in flexion-extension. The segmental ranges of motion, segmental flexion, and extension at every level of the lumbar spine were calculated by using functional radiographs. Besides providing normal values and segmental contributions, they reported that the iliolumbar ligaments regulate lumbosacral motion; especially flexion.

In 2001, a study considered disc degeneration and osteophyte formations on resultant segmental motions during flexion-extension. Tanaka et al[28] reported kinematic properties of the lumbar spine are related to disc degeneration. Greater motion was found with disc degeneration, particularly in grades III and IV, in which radial tears of the annulus fibrosus are found. Disc space collapse and osteophyte formation as found in grade V resulted in stabilization of the motion segments.

In 2002, Pitkanen et al[22] correlated degenerative spondylolisthesis at the L3-4 level and at the L4-5 level and spondylolytic spondylolisthesis at the L5-S1 level on plain films to anterior sliding instability on flexion-extension films. They also reported that retrolisthesis, traction spurs, and spondylarthrosis at the L3-4 level were statistically significant determinants of posterior sliding instability.

In 2004, using a biomechanical investigation on facet and ligament influences on lumbar segmental motions, Lee et al[13] showed that lumbar ligament damage and facet damage greatly affects segmental motion on flexion-extension films. The effect of the facetectomy on the motion segment is insignificant under flexion. In extension, unilateral facetectomy and resection on the contralateral facet markedly alters the rotational motion and flexibilities as well as coupled motions. Also, unilateral complete facetectomy with resection of less than 100% on contralateral facet generates high facet load.

In 2004, Wong et al[32] studied 100 healthy volunteers, including 50 men and 50 women, in lumbar flexion and extension. Lumbar flexion-extension was assessed with an electrogoniometer and videofluoroscopy simultaneously. Intervertebral flexion-extension of each vertebral level was calculated. Radiologic images of the lumbar spine were captured during flexion-extension in 10 degrees intervals. A linear-linked pattern of the motions was observed in different genders and age groups. No statistically significant difference in the pattern of motion was found between genders. However, statistically significant difference in the slope of curves was found at all lumbar levels in subjects whose age was 51 years or older.

In 2004, Iguchi et al[11] stated that some previous authors consider flexion-extension radiographs to be of little value in evaluating instability. They stated the variation of results in evaluating radiologic instability is the result of limitations in previous researchers' methods. They studied sagittal translation and angulation at the L4-L5 segment. These were measured in flexion-extension films in 1,090 outpatients with low back and/or leg pain. The symptoms of four groups with and without 3-mm translation and with and without 10 degrees angulation were compared for all the patients and for 280 age-matched patients using a scoring system. The age-matched patients were followed up for 4.6 years. Results showed that patients with ≥ 3mm translation had significantly lower scores, indicating a limitation in their daily activities due to pain, than patients < 3 mm translation. They reported no differences between the groups in terms of angulation. The group with ≥3-mm translation and ≥10 degrees angulation significantly demonstrated the lowest scores at both evaluations during the initial visit and follow-up. This

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group had been suffering from low back and/or leg pain the longest and had visited the hospital significantly more often than other groups. They stated translation of the lumbar segment has a greater influence than angulation on lumbar symptoms.

Outcome Investigations

Monitoring and/or evaluating differences in global and segmental motion and patterns in low back pain patients via chiropractic treatment have been done.

Bronfort and Jochumsen[1] determined that "*specific manipulative therapy can objectively increase the intersegmental mobility of the lumbar spine.*" In a randomly chosen group of seven patients out of an original group of 75 with chronic low back pain (CLBP), follow-up functional radiographs were obtained after a months worth of chiropractic treatment. They noted that "*contrary to reports by other investigators, this indicates that this mode of treatment might be able to increase the intersegmental mobility of the lumbar spine.*"[1]

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D. Pelvic Views

15. AP Ferguson

RECOMMENDATION

The AP Ferguson Radiographic view is indicated for the routine quantitative assessment of the biomechanical components of vertebral subluxation. This radiographic view has reliability, validity and clinical outcomes data that evidence its clinical utility in clinical chiropractic practice. When using this radiographic view, a baseline value of the biomechanical component of spinal subluxation should be determined prior to the initiation of chiropractic treatment intervention. In this manner, response to care can be determined.

Supporting Evidence: Clinical Levels I, IV,V, Reliability Studies Class 1 and 2, Population Studies Class 1 and 2, Biomechanics, and Validity.

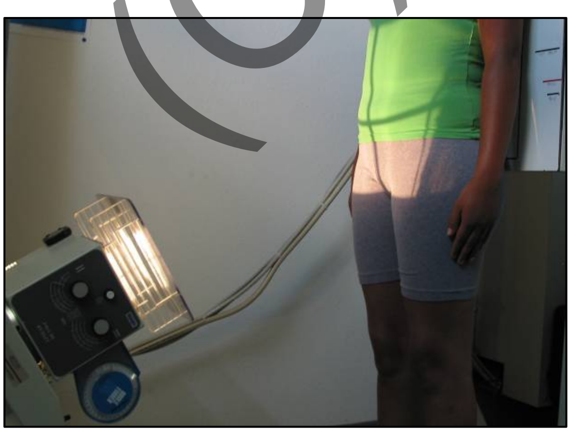
PCCRP Evidence Grade: Clinical Studies = B, C, D and Reliability, Population, and Validity studies = a

Introduction

The AP Ferguson (or just Ferguson View) sacral base radiographic view was originated by Albert Bartlet Ferguson in 1939[1]. This view was taken at a 45 degree tilt through the sacral base to eliminate the overlapping of the vertebrae. This view allows for optimal clarity of the sacral wings and pelvis. His book states that a radiological examination of the lumbosacral spine is not complete without this view.

The AP Ferguson view is taken standing with the heels directly underneath the patient's hips/femur heads so that the legs are parallel. Their toes are lined up with overt pronation or supination removed to prevent dropping of the tibia. All pelvis rotation must be removed by centering the pubic symphysis and the S2 tubercle to remove any asymmetrical magnification projection. The central ray should be tilted cephalad through the L5 disc space (between the anterior superior iliac spine (ASIS) and the iliac crest). The degree of cephalad tilt should be measured off of the lateral view. **Figure 1** depicts patient positioning and a sample radiograph.

This view requires a little more work in equipment and positioning time compared to an AP Lumbar view. The specialized equipment includes a tilt-able x-ray tube, a laser aligned x-ray frame that will ensure the cassette, tube, and floor are all level with each other. A lateral lumbar x-ray must be obtained of a subject in order to determine the tilt and height of the x-ray tube compared to the subject's sacral base angle. This tilt and tube height is derived from the sacral base angle to horizontal measurement in degrees from the lateral lumbo-pelvic view.



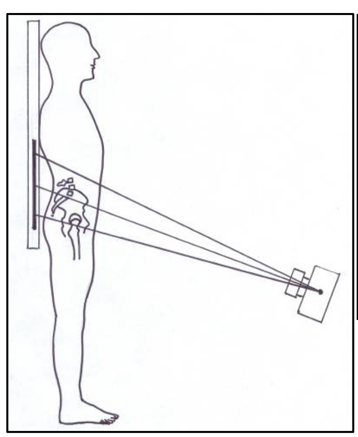


Figure 1 AB. In AB, the patient positioning for the AP Ferguson is shown with the central ray bisecting approximately the ASIS and the top of the iliac crest.

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Reliability of Line Drawing Procedures

In the late 1800's a number of studies were published on leg length inequality[2], with standing radiographs for postural analysis by Schwab and Hoskins from 1921 to 1934[3]. There are many different methods of evaluating leg length inequality (LLI), sacral base un-levelness (SBU), and pelvic obliquity (lateral tilt). A review of the literature finds that radiographic evaluation is both valid and reliable compared to unreliable or invalid clinical (palpation of landmarks).[5,9,11,36] Measurements are made on the AP Ferguson view in millimeters or degrees to analyze both the sacral base levelness and the femoral head levelness relative to horizontal.

Concerning radiographic assessment, there are several different measurements utilized to determine LLI. The two most common on the AP Ferguson are: 1. pelvic obliquity and 2. femur head level to horizontal measures. Figure 2 demonstrates the pelvic obliquity method. Both the pelvic obliquity and femur head level methods are reliable at determining LLI, but they provide different information; where the former is the measure of levelness of the sacral base and the later is a direct measure of the left versus right femur head level.

Bailey and Beckwith[4] may have been first to draw a line along the sacral base though vertical lines extended up from the apex of the femur heads (Right Triangle Method in Figure 2A). In a reliability study with 52 radiographs and 4 examiners, Fann et al[36] found good to high Pearson correlation coefficients and percent agreement for the right triangle method. Tilley[37] assessed the reliability of measuring different landmarks of the pelvis for pelvic obliquity and found good reliability.

The reliability of using differences in femoral head height has been established. Studies have identified a standard error measurement of 1-3mm for radiographic assessment of left versus right femur head measures.[23,38-43]

Using either of the two methods in Figure 2, the measured difference needs to be reduced by up to 25% to account for the x-ray magnification or enlargement. As an example, Juhl et al[2] found that the femoral head measurement were magnified between 12% and 20% depending on AP diameter of the pelvis.

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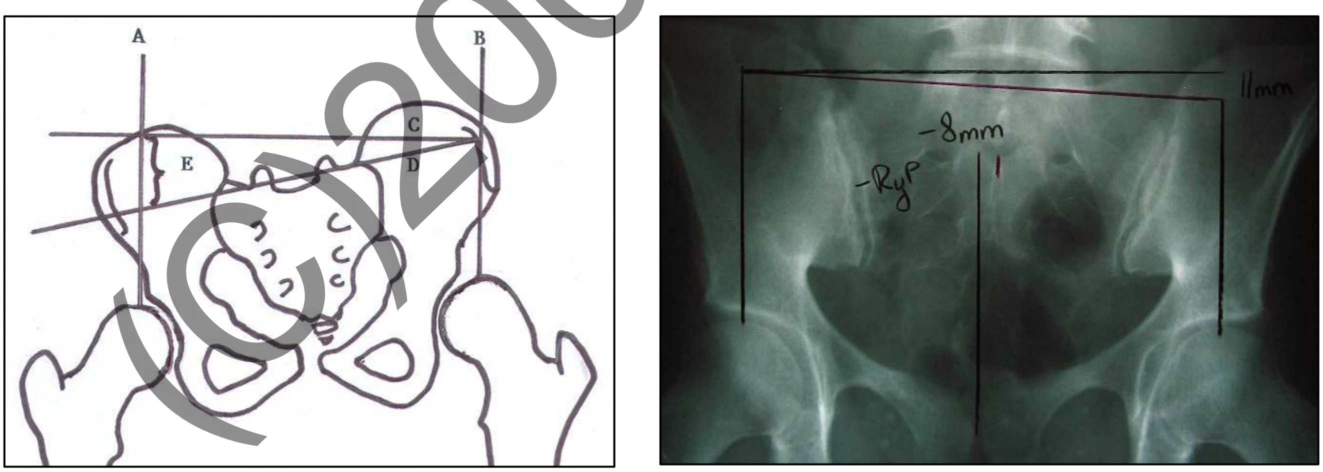

Figure 2 AB. In A and B, the Right Triangle method of calculating the lift in millimeters to be placed in the shoe of the low sacral side is shown. First, two lines are drawn vertically up from the apex of each femur head. Second, a line drawn across the true sacral base is extended to the left and right widths of the femoral head lines. Third a Horizontal is drawn across the width of the femur heads originating at the superior sacral line where it meets the femur vertical line. The height of the right triangle is theoretically the height of the lift needed in the shoe on the low sacral side to level the sacral base. The vertical line through the pubic symphysis is compared to S2 Tubercle for a measurement of pelvic rotation about gravity relative to center. Distances are magnified by 20-25% and must be clinically accounted

Reliability of Patient Positioning

At least 7 separate studies have been performed on repeated AP pelvic radiographs on the same subjects with both an intra and inter day and multiple examiner methods. Without exception, excellent reliability has been found for repeated measures on repeat radiographs for LLI. Using repeated radiographic views of the same subject, Giles and Taylor[39] and Clark[40] found a standard error of repeatability of femur head measures of 1-3 mm. In both studies, there was intra and inter-rater reliability and x-rays were taken by different radiographic technicians. Similarly, Beal[38] and Friberg et al[41] found repeatability of femur height of 1-2mm in repeated radiographs taken from 1-30 months after the patients' initial radiographic examination. Leppilahti et al[42] examined the radiographs of 15 subjects taken at 2 separate intervals on the same day. A mean error of repeated measures for femur head differences were 1.0mm, with a range of 0-2mm and a correlation coefficient of 0.96.

In 105 patients with chronic low back pain, Friberg[44] retook pelvic radiographs in order to analyze the consistency of anatomical leg length inequality and pelvic rotation about the gravity axis. Radiographs were repeated after an interval of 2 weeks to 3 years. The mean error between repeat x-rays was 0.7 mm for anatomical leg length and in 46 out of 105 subjects an analysis of pelvic rotation ranged from 0-3.0° with a mean of 0.9°.

Plaugher et al.[45] studied the reliability of patient positioning utilizing anterior-posterior pelvic radiography. There were 20 volunteers that had repeat radiography after approximately 1 hour and 17 subjects who received follow-up radiography after 18 days. The authors chose Gonstead technique line drawing procedures for analysis of the pelvis and leg length discrepancies. In the first group, the results showed there were no statistically significant differences ($p > .05$) between the two radiographs at one hour apart. The second group showed similar results at an average of 18 days ($p > .05$).

Diagnostic Capabilities

Juhl et al[2] found a low correlation between femur head un-levelness (FHU) and sacral base un-levelness (SBU). Therefore, pelvic obliquity, which measures the amount of lateral bending or z-axis rotation created in the pelvis, may be method of choice on the AP Fergusson radiograph. Leveling the sacral base makes better sense than leveling the femur heads because the pelvis is not always symmetrical and the goal in musculoskeletal treatment is to remove imbalance to lessen the stresses of gravity on the body.[46-49]

The AP Ferguson gives the doctor the clearest view of the lumbo-sacral junction with the least amount of distortion and asymmetrical magnification allowing for a more accurate measurement of the sacral base levelness. This view is accepted for the assessment of the sacral iliac joints, transitional vertebra, lumbo-sacral disc degeneration and for other anomaly detection.

Validity

An estimated 90% of the population has a LLI of 5mm or more.[35] Importantly, the prevalence and size of the LLI is significantly greater in pain groups versus symptomatic subjects.[23,24,39,44] Studies have found that LLI correlates to lower back pain (LBP) and radiographic evaluation has been shown to be the most accurate method to evaluate it.[5-20]

Oddly, regarding validity of LLI assessment, the recent CCGPP "Best Practices" Guidelines stated, on page 78: "*Finally, the procedure [radiographic measurements] has not been studied as to its validity, making the use of this as an outcome questionable (59).*"[51] Interestingly, their[51] reference #59 is a 1985 literature review by Lawrence. In direct opposition

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to this CCGPP statement,[51] recent and past validity investigations on assessment of LLI and sacral unleveling have found that radiographic evaluation is the most accurate and valid.[2,5,7,9-11,16,37,40,41] Apparently, the CCGPP committee[51] did not investigate this topic thoroughly.

LLI shows a correlation to unleveled sacral bases although the relationship is not directly proportional. [2,13,19] For example, in the study by Juhl et al[2], of 421 patients with LBP, most were found to have LLI (leg length inequality) and sacral unleveling on the same side. However the LLI and sacral unleveling were not always proportional; Juhl discussed the importance of measuring sacral base unleveling (SBU) and not just femoral head unleveling (FHU).

Summarily, the alignment of the AP Ferguson-pelvic Radiographic view as been found to correlate to and have predictive validity for the following conditions:

1. low back pain,[22-24,39,44,52]
2. sacral base unleveling correlates to the side of LLI,[2,13,19]
3. lumbo-sacral facet joint arthritis,[33,34]
4. lower-leg stress fractures,[33,34]
5. various chronic musculoskeletal pains,[48,49]
6. some visceral disorders.[48,49]

In contrast to the above validity information, two investigations have questioned the AP Fergusson/pelvic views validity.[50,53] For example, one investigation has found that the sacral tilt to horizontal in the coronal plane on the AP Pelvic radiograph does not correlate to lower back pain.[50] However, this report, did not assess their control group without lower back pain using standardized questionnaires of any type. Furthermore, the authors go on to state that they still use lift therapy to level the sacral tilt (pelvic obliquity) in their clinic for patients with chronic low back pain and that this seems to be effective. Secondly, Robbins et al,[53] reported on one hundred consecutive patients in whom radiographs of the sacroiliac joints (similar to the AP Fergusson view) had been requested concurrently with radiographs of the lumbar spine and/or pelvis. They concluded that "*In no case did the sacroiliac joint radiograph result in a normal diagnosis being changed to abnormal.*" However, Robbins et al,[53] did not look at LLI and sacral unleveling. The astute clinician may replace the standard AP Lumbar with a "modified AP Fergusson" tilt up x-ray view to avoid repeated views if desired.

It is the consensus of the PCCRP panel that the number and quality of investigations finding a correlation between the AP Fergusson-pelvic radiographic alignment and the conditions in the above 6 categories is superior to the few negative correlation studies. Thus, we conclude that the AP Ferguson-pelvic radiographic alignment has positive correlation and predictive validity for these 6 categories. [2,13,19,22-24,33,34,39,44,48,49,52]

<u>Outcome Studies Leveling the Sacral Base</u>

Correction of LLI and sacral unleveling with shoe orthotics has shown symptomatic improvement in several chronic pain populations.[10,21-32,39,47-49,52,54] Prevention of future lumbar degeneration and stress fractures has also been suggested as benefit of reduction of LLI.[33,34] Furthermore, a high compliance has been shown with the use of heel lifts.[28]

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Level I Studies:

In a recent randomized trial, Defrin et al[22] found statistically significant improvements in chronic low back pain in patients receiving shoe lifts compared to no treatment in the control subjects. In both the control and lift treatment groups, the measured LLI was less than 10mm as measured via radiograph.

Level II Studies: No level II studies could be located.

Level III Studies: No Level III studies could be located.

Level IV Studies:

Some authors have suggested that the right triangle method to level the sacral base might be a better method for clinical significance patient outcomes. In 2 separate investigations by Irvin[48,49], chronic musculoskeletal pains were alleviated by leveling the sacral base on the AP Ferguson radiograph. Of interest, several visceral conditions were found to be improved as well.

Dulhunty[54] reported on the successful management of 3 patients with various musculoskeletal complaints, including back pain and restricted ranges of movement. A multi-modal treatment approach was utilized including shoe lift therapy to reduce the amount of pelvic-sacral obliquity as measured via x-ray.

Conclusion

Because there is such a high incidence of LBP in the general population (85% in some studies) and there appears to be a high correlation of LBP to LLI and SBU[2], the AP Ferguson view should be a part of the routine x-ray series performed on all patients with a symptomatic history of spinal pain, leg pain, hip pain, knee pain or abnormal postures evident on physical evaluation. The available data support the use of corrective orthotics to reduce radiographically identified LLI and SBU. Clinical judgment in combination with this literature should aid in the reduction of subluxation/biomechanical alterations in both symptomatic and asymptomatic populations of patients presenting to chiropractic clinicians.

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16. AP Femur Head Radiographic View

RECOMMENDATION

The AP Femur Head Radiographic view is indicated for the routine quantitative assessment of the biomechanical components of vertebral subluxation. This radiographic view has reliability, validity and clinical outcomes data that evidence its clinical utility in chiropractic practice. When using this radiographic view, a baseline value of the biomechanical component of spinal subluxation should be determined prior to the initiation of chiropractic treatment intervention; response to care can then be determined.

<u>Supporting Evidence</u>: Clinical Levels I, III, IV,V, Reliability Studies Class 1 and 2, Population Studies Class 1 and 2, Biomechanics, and Validity.

<u>PCCRP Evidence Grade</u>: Clinical Studies = B, C, D and Reliability, Population, Biomechanics and Validity studies = a

Introduction

The assessment of the patient with observed gross postural distortion is incomplete without the analysis of a weight bearing radiographic view of the pelvis and lumbar spine, including the femur heads. When thoraco-lumbar-pelvic postural asymmetry exists, further investigation of the patient's structure is needed to accurately assess the root source of the asymmetry. The AP femur head projection is a valuable tool for the chiropractic clinician to evaluate a patient's structural abnormalities and many chiropractic techniques utilize assessment of leg length to determine their clinical approach to the patient. Radiographic information is the gold standard for determining lower limb inequality.[1-10]

The AP Femur Head Projection (APFH) is exposed at 40" focal film distance. The projection is exposed with the patient standing with weight even on both feet, with the pelvis centered with the center of the bucky or film holder in such a way as to align the pubic symphysis with the second sacral tubercle. The patient's feet are in a neutral anatomical position and are positioned femur head width apart. The patient is in bare feet and is instructed to relax in a natural stance. The patient's bilateral gluteal musculature will be lightly touching the bucky or film holder. In the horizontal dimension, the central ray will be positioned as close to the femur head height as possible. See Figure 1.

The APFH is utilized primarily to determine the measurable discrepancy in a patient's leg length, to confirm or refute the existence of a structural limb length discrepancy. The AP Femur Head Radiographic Projection is not usually a stand-alone radiograph. It is most effectively utilized as an additional assessment of the AP Ferguson and along side a standard weight bearing Anterior- Posterior Lumbo-Pelvic view. This is due to the fact that some patients can have anomalies of the sacrum/pelvis that correct for the leg length inequality.[2]

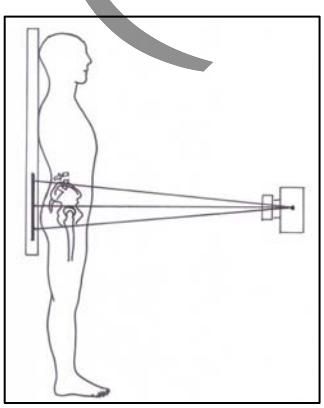

Figure 1. The AP Femur Head Radiographic (APFHR) view is taken at 40 inches with the central ray at the height of the femur heads and parallel with the leveled floor. The patient's feet are femur width apart, the pelvis is centered relative to the film and central ray, and any gross postural abnormalities should be removed to identify the true short leg anomaly.

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Reliability of Line Drawing Analysis

Classically, using the APFH x-ray view, a line is constructed consisting of two points, the highest point of the top of each femur head. A line is then constructed level with and parallel to the floor and at the level of the most cephalad femur head and another short line is constructed parallel with the floor or the more caudad femur head (relative to the other femur head of course). The difference between the two femur head heights is measured and recorded. See Figure 2.

A review of the literature finds that radiographic evaluation is reliable compared to unreliable clinical (palpation of landmarks). A multitude of studies have identified excellent inter and intra examiner reliability of leg length inequality with a standard error of measurement of 1-3mm for radiographic assessment of left versus right leg length measures.[11-26]

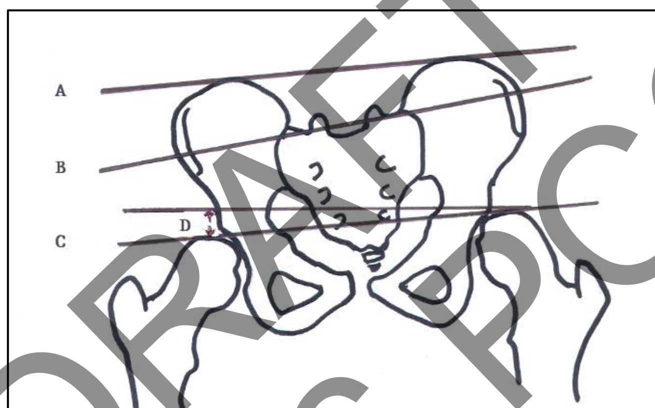

Figure 2. Measurement of leg length inequality on the AP Femur Head Radiographic View. Line A is across the superior aspects of the iliac crest. Line B is drawn across the sacral base. Line C is drawn across the superior aspect of each femoral head. A horizontal line (not labeled) is drawn across using the height of the superior femur head. The Distance D is the leg length inequality and is the vertical distance from the superior aspect of the 'short' femur to the horizontal line. Some authors only consider the Distance D to be significant if it matches the tilt of line segments A and B and the side of lumbar spine curve convexity.

Reliability of Patient Positioning Procedures

At least 7 separate studies have been performed on repeated AP pelvic radiographs on the same subjects with both an intra and inter day and multiple examiner methods.[12-16,27,28] Without exception, excellent reliability has been found for repeated measures on repeat radiographs for LLI. Using repeated radiographic views of the same subject, Giles and Taylor[13] and Clark[14]found a standard error of repeatability of femur head measures of 1-3 mm. In both studies, there was intra and inter-rater reliability and x-rays were taken by different radiographic technicians. Similarly, Beal[12] and Friberg et al[15] found repeatability of femur height of 1-2mm in repeated radiographs taken from 1-30 months aft the patients' initial radiographic examination. Leppilahti et al[16] examined the radiographs of 15 subjects taken at 2 separate intervals on the same day. A mean error of repeated measures for femur head differences were 1.0mm, with a range of 0-2mm and a correlation coefficient of 0.96.

In 105 patients with chronic low back pain, Friberg[27] retook pelvic radiographs in order to analyze the consistency of anatomical leg length inequality and pelvic rotation about the

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gravity axis. Radiographs were repeated after an interval of 2 weeks to 3 years. The mean error between repeat x-rays was 0.7 mm for anatomical leg length and in 46 out of 105 subjects an analysis of pelvic rotation ranged from 0-3.0° with a mean of 0.9°. Plaugher et al.[28] studied the reliability of patient positioning utilizing anterior-posterior pelvic radiography. There were 20 volunteers that had repeat radiography after approximately 1 hour and 17 subjects who received follow-up radiography after 18 days. The authors chose Gonstead technique line drawing procedures for analysis of the pelvis and leg length discrepancies. In the first group the results showed there were no statistically significant differences ($p > .05$) between the two radiographs at one hour apart. The second group showed similar results at an average of 18 days ($p > .05$).

Validity

Multiple studies have compared the means, standard deviations and frequency distributions of femoral head inequality in control subjects versus various pain groups. Concerning chronic low back pain populations, the data indicates that there is a statistically significant larger mean value of inequality and greater frequency of occurrence for difference as small as 4mm but much stronger data for differences of 10mm or greater.[11,13,24,27,29] Other authors have found a statistically significant relationship between the side of leg length inequality and side of lower back pain.[55]

Some authors have questioned the validity of the APFH radiographic view. For example, the recent CCGPP "Best Practices" Guidelines stated, on page 78: "*Finally, the procedure [radiographic measurements] has not been studied as to its validity, making the use of this as an outcome questionable (59).*"[56] Interestingly, their[56] reference #59 is a 1985 literature review by Lawrence.[10] In direct opposition to this CCGPP statement,[56] recent and past validity investigations on assessment of leg length inequality (LLI) and/or sacral unleveling on the APFH view have found that radiographic evaluation is the most accurate and valid.[2-9,14,15,18,21,37] Apparently, the CCGPP committee[56] did not investigate this topic thoroughly.

Significantly, the alignment of the AP Femur/pelvic Radiographic view as been found to correlate to and have predictive validity for the following conditions:

1. low back pain,[11,13,24,27,29,30,55]
2. knee injuries,[17,31-33]
3. lumbo-sacral facet joint arthritis,[34,35]
4. hip arthritis,[25,36-38]
5. lower-leg stress fractures,[39-41]
6. gait abnormalities with 2cm or more inequality,[42-44]

Oppositely, a few investigations have found that the AP Femur head alignment measurements do not correlate to and predict the findings in the above 6 categories.[37,45,46] However, part of this may be due to the lack of consideration of the pelvis, sacral base alignment, and lumbar alignment in some of these populations.[2,47,48]

It is the consensus of the PCCRP panel that the number and quality of investigations finding a correlation between the APFH Radiographic alignment and the conditions in the above 6 categories is superior to the negative correlation studies. Thus, we conclude that the APFH Radiographic view has positive correlation and predictive validity for the above 6 categories.[11,13,17,24,25,27,29,30-44,55]

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Outcome Studies

The use of heel and heel and sole lifts is common practice in many structural approaches to patient care and management. By establishing a base line analysis with the patient exhibiting asymmetrical leg length, repeat projections exposed with the addition of a heel or heel and sole lift can be exposed and analyzed to determine the effect of an orthotic or lift on lumbar and pelvic weight bearing and leg length equality.

Many clinicians will immediately expose an additional radiograph with the same parameters as the original to determine the effect on the patient's structure. Other clinicians advocate a gradual "build-up" of the lift to allow the soft tissues time to accommodate the change in femur head height.

Multiple investigations have been performed using shoe lifts to level leg length inequality in a variety of pain populations and in patients with spinal deformities. These studies suggest that lift therapy determined by radiography has positive correlation to patient pain and disability improvements.[11,13,26,32,38,49,50-54] The majority of these investigations are Level III and Level IV studies.

Level I Studies:

For example, in a randomized trial, Defrin et al[54] found statistically significant improvements in chronic low back pain in patients receiving shoe lifts compared to no treatment in the control subjects. In both the control and lift treatment groups, the measured LLI was less than 10mm as measured via radiograph.

Level II Studies: No Level II studies could be located.

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E. Full Spine Views

17. AP Full Spine Radiographic View

RECOMMENDATION

The AP Full Spine Radiographic view is indicated for the routine quantitative assessment of the biomechanical components of vertebral subluxation. This radiographic view has reliability, validity and clinical outcomes data that evidence its clinical utility in clinical chiropractic practice. When using this radiographic view a baseline value of the biomechanical component of spinal subluxation should be determined prior to the initiation of chiropractic treatment intervention. In this manner, response to care can be determined.

Supporting Evidence: Clinical Levels IV and V, Reliability Studies Class 1 and 2, Population Studies Class 1 and 2, Biomechanics, and Validity.

PCCRP Evidence Grade: **Clinical Studies = C, D and Reliability, Validity, Biomechanics = a.**

Introduction

As referenced by Rowe,[1] in 1932 a chiropractor named Sausser[2,3] took the first 14" x 36" AP Full Spine x-ray. Many chiropractic techniques utilize this radiographic view, including Gonstead, Toftness, Logan Basic, Meric, and Diversified (Figure 1). Additionally, it is the view of choice for a determination of scoliosis.[4] In his classic 1985 text, Hildebrandt[5] suggested that there are five projections that comprise a complete full spine analysis, one of which is the AP Full Spine view:

1. AP full spine,
2. Lateral full spine,
3. Femoral head view,
4. Sacral base view,
5. Upper cervical view.

The AP full spine view requires a 14in X 36in screen and grid cabinet. This view is taken with a tube-grid distance at 72in and can be taken at 84 in. One tries to have the occiput and femur heads all visualized on the 14 X 36 in film. It is often obtained in 2-3 takes with split screens.[6,7] Proper positioning for this view can be found in a text chapter by Rowe[1] and Yochum and Rowe (pp. 44).[8]

Reliability of Line Drawing Methodology

In chiropractic, the wedge angle method is the most common radiographic analysis on AP Full Spine radiographs.[6] In 1991, Plaugher and Hendricks[9] performed a pelvic mensuration reliability study on 71 AP full spine radiographs with two examiners marking each film twice. High reliability was ascertained with the Pearson r, Spearman, intra-class correlation coefficient (ANOVA) and Kappa statistics. All results were statistically significant ($P < 0.001$) and indicated high levels of concordance.

Additionally, the Gonstead technique utilizes the end plate line analysis that is inherent with in the Cobb angle method.[4,10-15] The Cobb method have been shown to have high reliability.[10-13]

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Figure 1. The AP full spine view is one of the most often utilized radiographic views in chiropractic. It is usually taken at a 72in focal-film distance. For a complete biomechanical analysis, it is desired to have the occiput, all cervical vertebrae, all thoracic vertebrae, all lumbar vertebrae, and the pelvis with femur heads visualized on this view. Hildebrandt suggested that the view be taken with the mouth open to visualize C1 and C2 as best as possible. The pelvis should be centered relative to the left/right film with no rotation about gravity

For example, Shae et al[10] reported on a reliability study where 24 AP full spine scoliosis radiographs were measured by six examiners. Two measurement sets were done manually ("manual set"), and two measurement sets were done on digitized images using a computer mouse ("computer set"). For the manual set, the 95% confidence interval for intraobserver variability was 3.3 degrees (range, 2.5-4.5 degrees). For the computer set, the value was 2.6 degrees (range, 2.3-3.3 degrees). This difference in 95% confidence intervals between the manual and computer sets was statistically significant ($P < 0.001$). Their[10] results demonstrate that intraobserver variability for manual and computer Cobb angle measurements yield a 95% confidence interval of approximately 3 degrees, with the computer having a slightly lower variability.

In 1990, Carman et al[12] stated that for measurements of scoliosis on AP full spine views, "*the average difference between readings was 3.8 degrees, and 95 per cent of the differences were 8 degrees or less (range, 0 to 10 degrees). These findings were in keeping with those of other published reports.*"

For another example, Morrissy et al[13] reported on the intrinsic error in measurement for 50 AP full spine radiographs of patients who had scoliosis. AP full spine films were each measured on six separate occasions by four orthopaedic surgeons using the Cobb method. "*For*

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the first two measurements (Set I), each observer selected the end-vertebrae of the curve; for the next two measurements (Set II), the end-vertebrae were pre-selected and constant. The last two measurements (Set III) were obtained in the same manner as Set II, except that each examiner used the same protractor rather than the one that he carried with him. The pooled results of all four observers suggested that the 95 per cent confidence limit for intra-observer variability was 4.9 degrees for Set I, 3.8 degrees for Set II, and 2.8 degrees for Set III. The inter-observer variability was 7.2 degrees for Set I and 6.3 degrees for Sets II and III. The mean angles differed significantly between observers, but the difference was smaller when the observers used the same protractor."[12]

Besides the Cobb method of Scoliosis analysis, the Risser-Ferguson method is also popular.[4,14,15]

Reliability of Patient Positioning

If the subject is positioned with the heels squared to the grid cabinet, there has been some criticism of the AP full spine view whenever the subject has pelvic axial rotation compared to the feet.[16] In such a case, the pelvis and whole spine is in a slight oblique position to the central ray. This criticism can be largely overcome by centering the pelvis to the central ray and positioning the subject using a neutral resting posture.[17]

Several investigations have been performed on the test re-test reliability of patient positioning for the AP/PA full spine or sectional AP thoracic measurements.[18,19-24] Problematically, many authors have misrepresented the scientific evidence on this topic and offer their Class V opinion that radiographic positioning is a significant source of error for AP/PA thoracic spine measurements.[20,21] For example, Capasso[20] claimed that difference in the curve of up to 17° can occur between an AP standing radiograph compared to a that obtained with a positioning device. A review of pertinent studies provides a different conclusion.

In 1978, Dawson et al[22] took repeated AP full spine x-rays on 60 scoliosis patients in the upright and the scoliosis chariot (SC) positioning device on the same day. Fourteen subjects had 2 scoliosis chariot x-rays exposed within 5 minutes of each other (3 total x-rays in each of these 14 subjects). Average differences in Cobb angle between the AP full spine and SC view were 3.4°-7.5° (increasing as curve magnitude increased). The difference in 2 repeated SC views were all within ± 3°. The authors concluded that SC views for scoliosis were more repeatable.[22] However, repeated AP full spine views were not performed on the same subject. Therefore, this study shows that as long as the clinician uses the same positioning procedures, then high examiner reliability will be found. This study[22] was misinterpreted by Capasso.[20]

In 1982, Desmet et al[23] took AP and PA full spine x-ray views of 78 scoliosis patients with an average time of 5-15 minutes between radiographs. Strong correlation between curve measures on AP vs. PA full spine films was found; r = .960. The PA view demonstrated a mean increased curve of 1.71° compared to the AP view. In 5/128 curves a 9°-13° increase, in 19/128 curves a 6°-8° increase, and in 4/128 curves a 6°-8° decrease on the PA film was found. The difference in curve values is due to projection of endplates on PA vs. AP films. However, this study does not indicate that positioning is a source of error as long as the same procedures are followed.

In 1995, Kohlmaier et al[24] took 2 AP full spine x-rays (standing and in a positioning device) of 100 scoliosis subjects. They concluded that the balance-like positioning device can standardize spine X-rays when the patient is standing, providing better reproducibility, more accurate prognostic aspects and fewer ionizing hazards. However, Kohlmaier et al[24] did not

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actually investigate the repeatability of the same position on each subject therefore no conclusions can be drawn.

In order to investigate positioning errors, Sevastikoglou and Bergquist[19] took 17 frontal plane radiographs of 2 scoliosis skeletons: neutral, rotation up to 10° left/right and 5 cm elevation or depression of the tube height. Two examiners assessed the curves using the Cobb and Riser-Ferguson methods. They found little effect of rotation up to 10° and alteration in tube height by 5 cm on curve magnitudes. Differences in curve measurements hardly surpassed the error of the measurement techniques themselves. Average error for specimen 1 had the largest values: 1.15° ± 0.98° for Ferguson's method and 2.06° ± 1.09° for Cobb's method. This information[19] was misinterpreted and inaccurately reported by Capasso et al.[20]

Pruijs, et al,[18] investigated the repeatability and reliability of thoracic, thoracolumbar and lumbar Cobb angle measurements by studying two sources of error: the production of the radiograph and drawing/measuring the lines/angles. Regarding the production of the radiographs, the investigators compared serial radiographs in patients who underwent surgical spinal fusion for scoliosis and therefore had a fixed spinal curve. They discovered that the production of the series of radiographs produced a standard deviation in the Cobb angle of only 3.2°. This is often less than the standard error of measurement, as discussed previously in some studies. In other words, the measurement method may not be sensitive enough to detect any 'true' differences in the curve caused by positioning.

Based on the above review, it is the consensus of the PCCRP panel that positioning procedures for exposing the AP Full Spine radiograph is reliable as long as the same procedures are followed on initial and repeat films. We recommend that the pelvis be centered relative to the bucky in order for less distortion and a more accurate analysis.

Diagnostic Capabilities

The AP full spine radiographic view is the choice of views for diagnosing scoliosis and for measuring with Cobb angles. As such, it is a cross over view in medicine and chiropractic. It is the only view on which the balance of all the spinal regions (cervical, thoracic, and lumbar) posture can be visualized. On this view, one can measure the total alignment changes caused by fractures, hemi-vertebrae, short leg discrepancy, laterolisthesis, and many other pathologies and anomalies.

Validity of the AP Full Spine View

There are several issues to consider when addressing the validity of the AP Full Spine radiographic view. First is the radiation exposure level that a patient would experience. According to Rowe, "*An AP full spine view using a 400 film screen speed combination yields about 145 mrem of total body exposture.*" And "*This would mean that a 30-year-old man would have to receive a minimum of 333 AP full spine expostures at 400 speed before the National Academy of Science guidelines would be met. A 1200 speed system with gonadal shielding would require more than 1000 AP full spine exposures to double the risk of the genetic mutation rate.*"[1] This is using an annual dose limit of 10 Rem (See Section VII as well).

Cracknell and Bull[25] investigated and quantified the difference in both full-body effective doses and absorbed doses resulting from 3 AP sectional spinal x-rays (AP cervical, thoracic, and lumbo-pelvic) compared to the AP Full Spine radiograph. Using Lithium fluoride (LiF) thermoluminescent dosimeters (TLD-100) placed on an accurate anthropomorphic phantom,

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doses were calculated. When compared with AP sectional exposures, the AP full-spine exposure gave consistently less absorbed doses to all critical organs.[25]

Kuklo[26] reported on 112 patients assessed and treated for proximal thoracic scoliosis and resultant shoulder imbalance. The AP Full Spine radiograph was used. The clavicular height was the only radiographic variable measured that was predictive for accuracy of shoulder height (measured as the soft tissue shadow on the film) in subjects treated surgically for scoliosis in three out of the four groups studied (P = .0009, .0193, .0716 and .0007).[26]

Outcome Investigations

This section is still be written.

Level I Studies:

Level II Studies:

Level III Studies:

Level IV Studies:

In 1977, the late I.N. Toftness self published his text with results from 100 cases utilizing AP full spine radiographs.[27]

In 1991, Plaugher et al authored a Gonstead text book with multiple cases studies utilizing the AP full spine view.[6]

In 1993, Haney[28] reported on a juvenile migraine head ache case with resolution of symptoms and pre-post AP full spine radiographic improvements.

In 1994, Araghi[29] reported on improvements in a 5 year old with oral apraxia, with concomitant improvements in alignment of pre-post AP full spine radiographs.

In 1996, Eriksen[30] reported on a scoliosis correction with upper cervical chiropractic care with a nasium pre-post and with an AP full spine pre-post reduction in the Cobb angle in both the thoracic and lumbar regions.

In 2004, Gilmour et al[31] reported on AP full spine scoliosis correction utilizing the Pettibon weighting system.

In 2004, Morningstar et al[32] reported on a retrospective case series of 19 subjects with scoliosis. Pre-post AP full spine radiographs showed a 17° reduction in curvature.

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18. Lateral Full Spine Radiographic View

RECOMMENDATION

The Lateral Full Spine Radiographic view is indicated for the routine quantitative assessment of the biomechanical components of vertebral subluxation. This radiographic view has reliability, validity and clinical outcomes data that evidence its clinical utility in clinical chiropractic practice. When using this radiographic view a baseline value of the biomechanical component of spinal subluxation should be determined prior to the initiation of chiropractic treatment intervention. In this manner, response to care can be determined.

Supporting Evidence: Clinical Levels IV and V, Reliability Studies Class 1 and 2, Population Studies Class 1 and 2, Biomechanics, and Validity.

PCCRP Evidence Grade: Clinical Studies = C, D and Reliability, Biomechanics, and Validity = a.

Introduction

In radiography of the spine, the full spine radiographic view is an accepted norm.[1,18] According to the Scoliosis Research Society,[1] "*…complete discussion of sagittal balance clearly needs to address both the axial skeleton and lower extremities, including the hips. Measurement of sagittal contours needs to be distinctly documented for useful comparison. The standing 3' radiograph with appropriate grids at a focal distance of 72" is clearly the accepted norm.*"

Care should be taken to insure that several structures are visible from at least the lower half of the skull superiorly to the pelvis and both femur heads inferiorly. For proper penetration and visualization, in almost all cases, a lateral cervico-thoracic filter and a lateral lower lung field filter (T7-T12) are needed in order to adequately visualize the entire spine.

In chiropractic analysis, the lateral full spine radiographic (LFSR) view should be taken in the upright standing position at the standard tube distance of 180 cm (72 inches) with the central ray located approximately at the T6-T7 disc level. Most commonly in todays practice, the LFSR is taken in one exposure on a 14 inch x 36 inch cassette and film; however it can be taken in two expostures.[31] For the LFSR view, the patient's arms must be positioned out of the field of x-ray view by placing the hands on a rest at iliac crest height[2], by holding arms out almost 90° in front grasping a stand,[3] or by folding the arms on the chest and placing the hands in the clavicular fossae.[4]

Since chiropractic clinicians are interested in the alignment of the patient's individual spine, the self balance position is most appropriate to ascertain the patient's unique subluxation alignment. The patient's abnormal sagittal plane posture should be left as is, i.e. it is not guided towards an ideal neutral position. Figure 1 depicts the 'self balance positioning' for the LFSR.

Reliability of Measurement Methods

The LFSR view measurements include the total curve measurements at a various cervical, thoracic, lumbar, and pelvic levels, sagittal balance (flexion/extension and sagittal translation) of the upper versus lower regional (cervical, thoracic, lumbar) levels, segmental vertebral curvature values from S1-C1, total sagittal balance with the C7-S1 and C1-S1 plubmlines, and pelvic morphology measurements. See Figures 2 and 3. These methods have been analyzed in a multitude of different ways on lateral full spine radiographs.[1-17]

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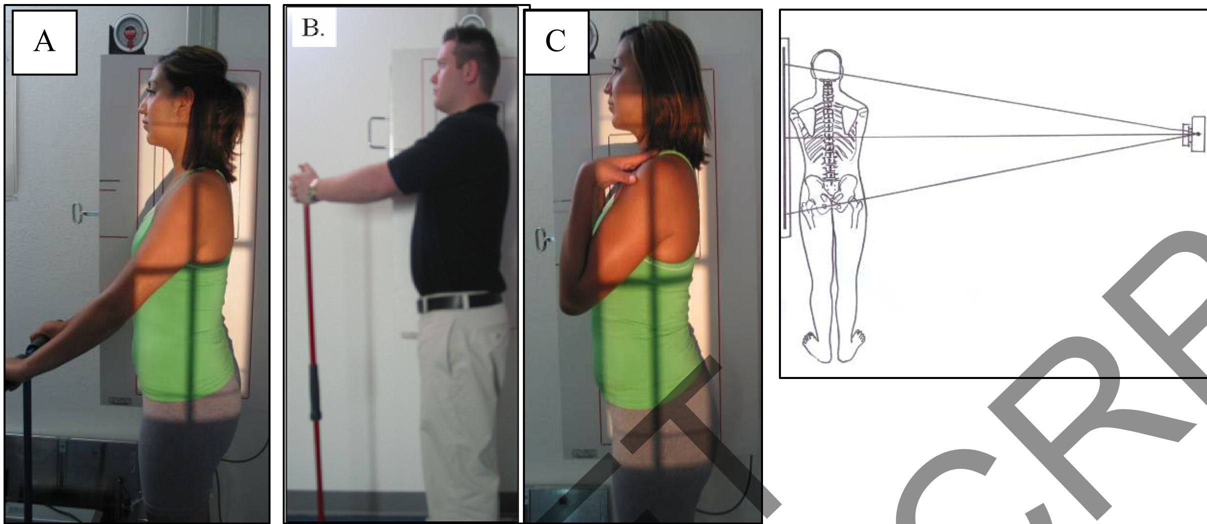

Figure 1 A-D. Self balance position for the lateral thoracic radiograph. In A, the patient assumes their neutral postural balance and then the arms are bent at the elbow and shoulder approximately 135° and the hands are placed on a rest at iliac crest height. In B, the patients arms are flexed nearly 90 at the shoulder and the hands are placed on a pole. In C, the patient assumes the 'self balance position' and then the arms are folded on the chest placing the hands in the claviular fossae.

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In a repeated measures design, Rillardon et al[12] used 100 films and 5 examiners to compare manual measurements and computerized measurements on the LFSR views. Intra-class ICCs varied from 0.82 to 0.96 and inter- and intra-observer variabilities were comparable for the measurement techniques for thoracic kyphosis, lumbar lordosis, pelvic index, pelvic tilt, and slope of the sacrum. Significantly, inter- and intra-observer variability was smaller when the sagittal tilt was measured with the computer.

In another LFSR view reliability study, Rajnics et al[11] investigated the inter and intra examiner reliability of several variables. Excellent reliability with small standard errors of measures were found (< ±1.5°) when the operator was designated as experienced. Less (±-6.5º) repeatable measurements were found for T4-T12 kyphosis due to poor contrast on radiographs of the upper thoracic vertebrae.

Collectively these studies indicate that measurement of the lateral lumbo-pelvic radiographic alignment has excellent observer reliability for a variety of methodology.[1-17]

Repeatability of Patient Positioning

Several investigations have been performed in an attempt to identify the optimal, repeatable LFSR view patient position.[2,4,7,13,14,16,17,19-21] These investigations clearly demonstrate that the LFSR alignment on follow-up radiographs is repeatable if standardized procedures are followed. There is a difference in sagittal balance with the 'functional' radiographic positioning procedures that place the arms too far out in front of the body's center of gravity. However, the lordosis and kyphosis stay relatively constant.

In general, this literature survey evidences that the positioning procedures for the hands at iliac crest height, with the shoulder flexed around 30°, elbows slightly bent and the arms folded on the chest with the hands in the clavicular fossae are the two most appropriate positioning for the LFSR view. See Figure 1A and 1C.

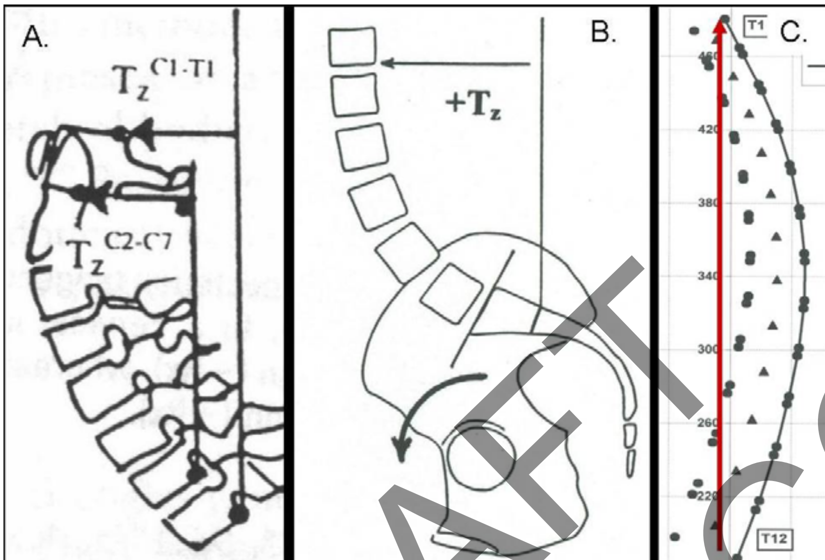

Figure 2A-D. In A, the cervical sagittal balance line is shown. In B, the thoraco-pelvic sagittal balance line is shown. In C, the regional thoracic balance plumbline is shown. In D, these lines are drawn on the full spine lateral view in order to determine full spine regional sagittal alignment.

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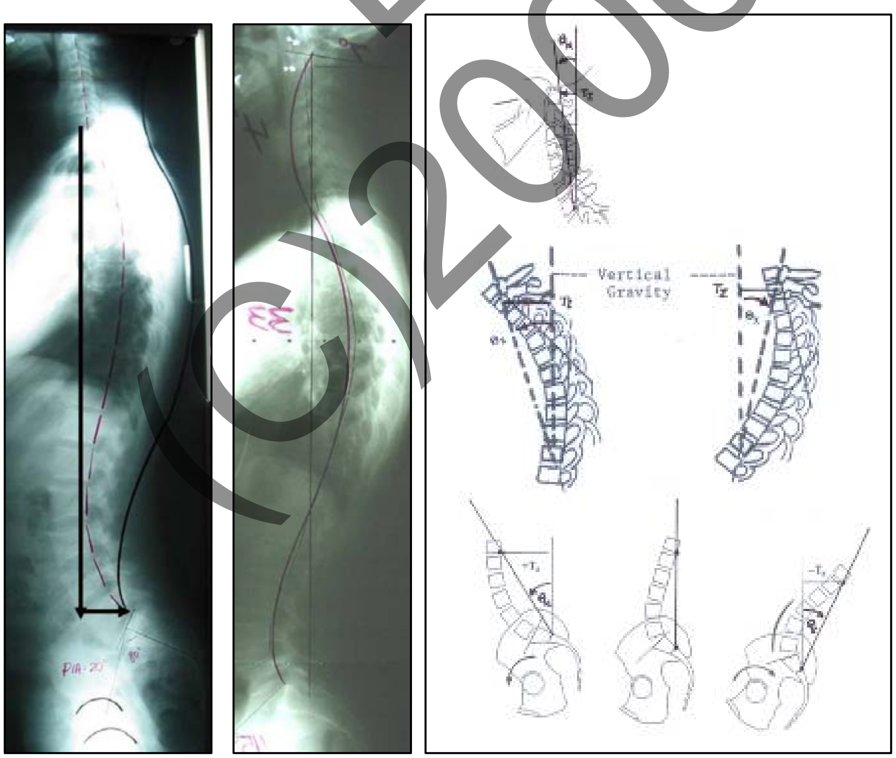

Figure 3. Lateral full spine sagittal balance and modeling measurements. In A, the C7-plumbline is shown. The centroid of C7 vertebral body is used to drop a vertical line inferiorly. The distance from this line is compared to the posterior superior body corner of S1. In B, the S1 plumbline is shown. A vertical line is drawn vertically upward from the posterior inferior body corner of S1. The horizontal distance of the posterior inferior body of T1 and posterior superior lateral mass of C1 is compared to this line. In C, the regional sagittal balance of the lumbar, thoracic, and cervical spines are shown on the full spine lateral using angular displacements from vertical of the upper versus lower spinal section.

Diagnostic Capabilities

When properly performed, lateral full spine radiograph will provide visualization of several structures, subluxation abnormalities, anomalies, and pathologies. The vertebral bodies, disc spaces, articular pillars, spinous processes, sacrum, and femur heads should all be visualized. The lateral full spine radiographic view provides the chiropractic clinician with valuable information including:

- a global view of the sagittal balance of C1, T1, T12, and S1,
- an evaluation of forward/backward head translation,
- an evaluation of forward/backward ribcage posture,
- an evaluation of sagittal posture (from the postural examination) and spinal coupling on the radiograph,
- an evaluation of cervical lordosis,
- an evaluation of thoracic kyphosis,
- an evaluation of lumbar lordosis,
- an evaluation of pelvic tilt
- an evaluation of pelvic morphology,
- an evaluation of any retro- or spondylo-listhesis and,
- an evaluation of spinal degeneration (vertebrae, discs, spinal ligaments),
- spinal canal dimensions, and
- a number of other anomalies, fractures, and instabilities.

Validity

Multiple investigations have been performed and found correlation and predictive validity of the lateral full spine radiographic alignment to a variety of health related conditions including:

1. back pain,[3,23]
2. full spine sagittal relationships to clearly identify hyper/hypo cervical lordosis, hyper/hypokyphosis, and hyper/hypolordosis,[1,5,6,10,15,21-24]
3. stress/strain relationships & degenerative joint disease (DJD),[6,22,25,26]
4. physical disability & functional impairments,[27,28]
5. risk of ageing deformity progression and vertebral body fractures,[29,30]

It is the consensus of the PCCRP panel that the number and quality of investigations finding a correlation between the lateral full spine radiographic alignment and the conditions in the above categories is of adequate quality. Thus, we conclude that the lateral full spine radiographic alignment has positive correlation and predictive validity for these categories.[1,3,5,6,10,15,21-30]

Outcome Investigations

Although many chiropractic techniques and clinicians utilize the lateral full spine radiographic view, only Level IV studies could be located on this view in chiropractic treatment outcome studies.[33,34]

Collectively, however, the data presented in the previous sections suggest that utilization of a multi-modal treatment approach, including chiropractic techniques, would show positive change on the LFSR view and that this might have the ability to improve a patients health, pain,

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and disability levels. These types of investigations need to be performed by practicing chiropractors and/or researcher investigators.

Level I Studies: No Level I studies could be located.

Level II Studies: No Level II studies could be located.

Level III Studies: No Level III studies could be located.

Level IV Studies:

Numerous case reports showing corrections of the biomechanical component of vertebral subluxations using the Full Spine Lateral radiography were presented by Plaugher[33] and Toftness.[34]

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19. Bending and/or stress films for the assessment of scoliosis or buckling

RECOMMENDATION

The Bending and/or Stress Radiographic views are indicated for the quantitative assessment of the biomechanical components of vertebral subluxation. This radiographic view should be obtained when significant scoliosis, buckling, or other unusual spinal configurations are present that do not match typical postural presentations in the AP view. These radiographic views have reliability, biomechanics, validity and clinical outcomes data that evidence their clinical utility in clinical chiropractic practice. When using this radiographic view a baseline value of the biomechanical component of spinal subluxation should be determined prior to the initiation of chiropractic treatment intervention. In this manner, response to care can be determined.

Supporting Evidence: Reliability studies class 1 and 2, Biomechanics, Population Class 2 studies, and Validity.

PCCRP Evidence Grade: Clinical Studies = C, D and Reliability, Biomechanics, and Validity = a.

Introduction

Stress films are commonly taken in the assessment of scoliosis flexibility. Surgeons take stress views to assess the flexibility of an idiopathic scoliotic curve prior to surgery to get an estimate of the amount of correction that can be achieved and to determine levels of fusion/instrumentation placement. Curve flexibility has been investigated for quite some time. It has been commonly accepted that the more flexible a curve, the higher the risk of progression if left alone, but the easier to change with non-operative treatment. There are currently several methods orthopedists and radiologists use to objectively detect the degree of flexibility of a structural curve.

One method commonly used is to take a full spine radiograph with the patient stressed into lateral flexion while in the prone position.[1] This has also been reported in the standing,[2] and supine positions.[3,4,5] The average correction obtained in a pure lateral bending stress film appears to be between 35-88%.[2,3,6,7] Variation may exist due to reporting on different curve patterns, age of subjects, etiology of the scoliosis and the technique used to obtain the stress film. Another variation of the lateral bending method has been reported. Cheung[7] placed patients in a side-lying position with the apex of the curve over round fulcrum; alternatively a 2-3 inch wide strap can be used to pull down at the apex of the curve. (**See Figure 1**) These side-lying, fulcrum-bending films have primarily been shown good results for reducing *thoracic* curves. This was confirmed by Luk, et al[9] in 1998 and Klepps et al[10] in 2001.

The last method found in the literature is the prone push film.[3,11,12] This method utilizes lateral translation (shear) forces applied by a technician while the film is taken with the patient lying prone. Both studies reported a 42% correction of the Cobb angle. Vendatam, et al,[3] conclude, “the current study of the prone push radiograph showed that it is superior to the lateral-bending radiograph in predicting the postoperative translation and rotation of the lowest instrumented vertebrae”. They note that the two methods investigated were similar in predicting Cobb angle improvement.

It is difficult to determine which, if any, technique is most effective, since most of these studies do not compare different methods within the same group of subjects. Factors, such as

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curve pattern, magnitude and sagittal alignment will most certainly affect vertebral coupling patterns in a different manner in response to the same main motion. With this in mind, different curves will respond to two or more main motion postural combinations in accordance with the biomechanical principle called the non-commutative property of finite rotation angles upon addition. This has been discussed in the literature and form the basis for scoliosis stress films described by Harrison.[13]

Some studies have described axial traction radiographic views. White and Panjabi[14] reasoned that axial distraction loading would only be appropriate in scoliosis curves exceeding 53°, while curves under 53° would respond better to transverse loads. Takahashi, et al[15] showed that, "In thoracic curves, the postoperative Cobb angle was highly correlated with the preoperative Cobb angle in traction (r = 0.82). However, such correlation was much lower with lumbar curves (r = 0.54). The reducibility of the thoracic curve by traction as expressed by the ratio to the original curve was dependent on the magnitude of the original curve (P = 0.005)".[15]

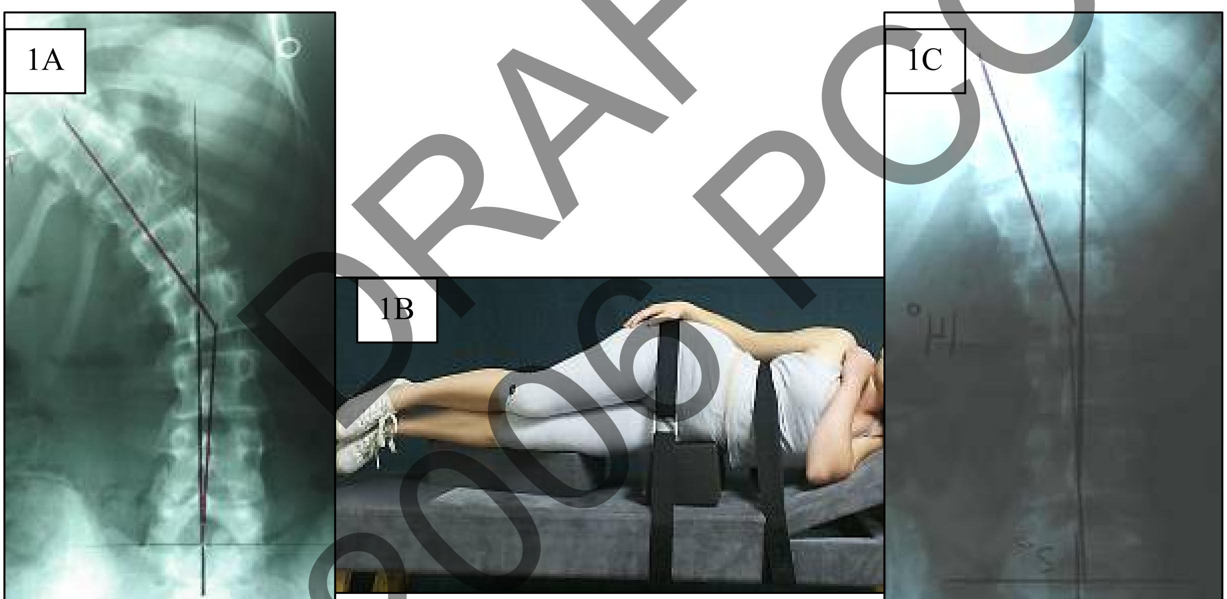

Figure 1A-C: Side lying scoliosis fulcrum-bending stress film. In A, the patient's standing pre-operative AP lumbar radiograph is shown. In B, the patient is positioned in left thoracic translation and right thoracic lateral flexion with movement emphasized to the thoraco-lumbar spine and an x-ray is taken. In C, the reduction of the curve on the stress film is shown. Reprinted with permission: Harrison CBP Seminars, Inc. 2005-2006.

Polly and Sturm[16](1998) demonstrated similar results comparing halo-femoral traction (longitudinal distraction) to supine side bending in a clinical study for curves above and below 60°. In 1982, Klienman, et al,[11] found conflicting results. They performed a study on 58 subjects using the prone push radiographs (transverse loads) to estimate postoperative correction. They found that for curves less than 50° (N=42 curves), an average of 18.9° of correction was achieved as compared to an average of 23.4° correction of curvatures over 50° (N=40 curves). They did not study the effect of axial traction forces. Average values of magnitude for the two

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groups of curves were not reported, nor were the percent correction of the two groups. From a non-operative, conservative clinical point of view, these findings are important to understand.

For all curves under 50-60°, intervention using axial traction will be less likely to effectively manage the curvature. Transverse loading and fulcrum bending are more appropriate. Since most patients seeking non-operative intervention have curvatures that fall into this range, this is where our focus lies. For magnitudes over 50-60° applications of axial distraction forces, also referred to “extension” by some authors,[17,18] may facilitate greater correction, even though transverse shear forces and fulcrum bending will still reduce the curve.[4]

It is also important to note that flexibility dramatically decreases as patient age and curve magnitude increase.[19] It has been estimated that every 10 degrees increase in curve magnitude over 40 degrees results in a 10% decrease in flexibility; every 10-year increase in age decreases flexibility of the structural curve by 5% and the lumbosacral curve by 10%.[19] Utilizing biplanar radiography, Matsumoto etal[20] demonstrated that axial traction significantly reduces the frontal plane deformity. However the axial rotation was persistent in curves greater than 40°. In a study comparing the flexibility of proximal thoracic curves in response to side bending versus axial traction, Kirk, et al,[21] found that the supine traction radiograph demonstrated greater flexibility of the proximal thoracic curve than the supine side-bending radiograph.

Reliability of Line Drawing Methodologies

The reliability of the Cobb, Risser-Ferguson and Harrison Modified Risser-Ferguson methods of frontal plane abnormality was discussed previously in Sections VIII and X. The same reliability studies supporting these methods apply to the analysis of the stress films.

Reliability of Patient Positioning

The reliability and reproducibility of the production of the radiographic image was discussed previously in this document and applies to the positioning of these patients and production of these films as well. However, care must be taken to either center the body part immediately below the scoliotic region or center the scoliotic curve apex to the center of the film.

Diagnostic Capabilities

Orthopedists order stress films prior to surgical treatment to assess flexibility of the curve and to help determine level of fusion. Chiropractors, on the other hand, have the capability to assess the flexibility of the spine to ascertain an approximate maximum potential correction. This is the only diagnostic means to assess the flexibility or reducibility of a scoliotic curve.

Validity of the Frontal Plane Scoliosis Stress Views

Stress films have shown good correlation for assessment of flexibility of a curve in that these views are predictive of post-operative curve correction.[1,8,11,12,15](Takahashi, Kleinman, Aronnson, Dobbs,Cheung,) For example, Takahashi, et al[15] showed that, “*In thoracic curves, the postoperative Cobb angle was highly correlated with the preoperative Cobb angle in traction (r = 0.82). However, such correlation was much lower with lumbar curves (r = 0.54).*
The reducibility of the thoracic curve by traction as expressed by the ratio to the original curve was dependent on the magnitude of the original curve (P = 0.005)”. [15]

Kleinman[11] found the difference in magnitude between the pre-operative prone push film and the post-operative film to be statistically insignificant (P = 0.34). In essence the more

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flexible a curve the more likely it will respond to operative treatment. This is also applicable to any conservative, non-operative intervention, including chiropractic.

Outcome Investigations

Level IV Studies:

Harrison, et al,[13] reported on five patients who experienced a significant reduction of scoliosis deformity after Chiropractic Biophysics protocols. Their procedures were based upon results of a unique method of obtaining stress films. They reasoned that large spinal deviations, such as seen in scoliosis patients, may respond differently when two main motions are applied to the spine in opposite orders ($A+B \neq B+A$). This rationale is based upon the non-commutative property of finite rotation angles under addition.

Speiser et al[22] and Grice et al[23] reported on before and after outcomes in a few patients where AP lumbar stress bending films were used to determine treatment type and direction.

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F. Motion X-ray/Videofluoroscopy for Kinematic Instability Evaluation

RECOMMENDATION

Production and analysis of videofluoroscopic, cineradiographic and digital motion X-ray images are a well accepted part of clinical chiropractic practice. The PCCRP panel recommends these techniques in patients with acute and chronic traumatic injuries, after surgical intervention, that have failed to respond to clinical intervention, and in patient's with pain reproduced by a specific spinal movement.

Supporting Evidence: Population Studies Class II-IV, Reliability Studies, Validity Studies, Biomechanics and Health, Basic Science Studies.

PCCRP Evidence Grade: Clinical Studies = B,C, D and Reliability, Biomechanics, and Validity = a.

Introduction

Fluoroscopy was first performed by Roentgen in 1895 during his seminary experiments with x-rays. Roentgen published his findings in the widely reprinted paper: W. C. Roentgen: About a New Kind of Rays. The following year, the fluoroscopic screen was invented by Italian scientist Enrico Salvioni. Shortly thereafter, Thomas Edison noted that calcium tungstate screens produced superior images to the barium platinocyanide used by Roentgen and Salvioni and the first commercially available fluoroscopes were produced.[1]

Some fifty years later, developments in fluoroscopic technology resulted in the image intensifier tube which permitted signal amplification, an improved image, a reduction in radiation exposure and output to a camera.[2] When fluoroscopic images are recorded to film, it is referred to as cineradiography. When a videocassette recorder is used to record the output, the procedure is referred to as videofluoroscopy.

Active range of motion of the vertebrae in the spine may be visualized by way of videofluoroscopic joint motion study examination. By observing motion of the spine in weight bearing, it is possible to identify abnormal motion patterns. In many instances it is possible to visualize unstable and abnormal vertebral motion patterns by direct observation. By capturing video frames and measuring translations and rotations with a computer assisted method, it is possible to apply geometric threshold criteria to objectively identify structural abnormalities.

Motion patterns are observed and interpreted diagnostically. The fluoroscopic images are the result of an x-ray tube running a continuous exposure aimed at an image intensifier. The tube and image intensifier are usually mounted on a c-arm frame. A Charge Coupled Device (CCD) camera is mounted behind the image intensifier aimed at the tube. The output of the CCD camera is recorded on a videotape, DVD or computer hard drive. Compared to plain film exposures, videofluoroscopy with an image intensifier can produce a diagnostic image from the same kV with the mAS factor in the order of 1/20 to 1/30 of that for plain film. Accordingly, a videofluoroscopy assessment of the cervical spine can be obtained with a dose roughly equivalent to a plain film Davis Series of the cervical spine.

The CCD camera output is simultaneously viewed on a monitor while being recorded on videotape (or DVD). Individual frames from the video stream may be captured and evaluated in the same manner as plain film images. Depending on the format of the camera's output, different lenses are used. For NTSC format video output, the first lens over scans the image creating a 4:3 aspect ratio and the second lens frames the image.[3] DICOM format video output has a 1:1 aspect ratio.[4]

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If computer analysis is being performed on captured images and plain film geometric values are being used, calibration of the output is required to account for the focal film distance (FFD) of the c-arm as well as output scale of the CCD camera and the pixel per inch (PPI) resolution of the images. However, this calibration will only affect translation (linear) measurements and not rotation (angular) measurements.

In 1991, The American Chiropractic College of Radiology and Council on Diagnostic Imaging released a position statement through the American Chiropractic Association regarding a protocol for the use of spinal videofluoroscopy (See Section VI). This position was also adopted by the Chiropractic College of Radiologists in Canada (See Section VI). While there have been significant technological advances since that time, there has been no modification to these original position papers. For example, minimum equipment recommendations as per the ACCR position statement included machines that were capable of generating at least 125 KvP at a range of 1-3 mA and a videotape recording device. Current machinery can operate at 100 KvP, 1-3 mA and produce better imaging than these "older" units and record the studies on videotape, DAT tape, DVD/CD-ROM or computer hard drives. Subsequently, other organizations such as the International Chiropractic Association have provided their own statements regarding the use of videofluoroscopy (See Section VI). It should be noted that as of March, 2006 position statements from the American Chiropractic College of Radiologists have been withdrawn from their web-site, pending review and possible update.

Technique

The technique of videofluoroscopy can be broken down into a number of components including an x-ray tube assembly, an image intensifier tube, a television camera, a videocassette recorder and a monitor.

Given advances over the last several years, it is prudent to distinguish videofluoroscopy from *digital* videofluoroscopy or digital motion x-ray, which primarily revolves around technological improvements to the image intensifier, monitor and recording components of the system. Since 1998, significant advances have been made in the use of charge-coupled-devices (CCDs) as well as amorphous silicon technology to allow for greater imaging ratios. This essentially translates to the need for less radiation to produce a better quality image. Image clarity, storage and review have also improved with the use of digital storage media. Figure 1 shows the machinery of and a subject positioned for Digital Motion X-Ray analysis of the cervical spine.

Figure 1. The machinery of and subject positioning for a cervical analysis using Digital Motion X-ray analysis. Reprinted with permission: Linda and Dr. John Postlethwaite, Digitial Motion X-ray®.

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Cervical Protocol

While videofluoroscopy can be used to assess extremities as well as the spine, the greatest advantage to the chiropractor will come from the assessment of spinal trauma and patients with pain upon specific movements only where no other objective findings are positive. Many fluoroscopic systems consist of an x-ray tube and image intensifier mounted on a 36 inch c-arm. This configuration is not well suited to assessment of the thoracic and lumbar due to patient thickness and close proximity of the patient's skin to the tube. The 36 inch c-arm configuration is extremely well suited to assessment of cervical spine trauma and focal film distance calibration can be normalized to the 72 inch standard for impairment rating from flexion and extension views.

The full cervical videofluoroscopy protocol consists of:

1. **Lateral nodding**, involving lateral observation of cervical motion when the center of mass of the head is rotated posterior by raising the chin.

2. **Flexion and extension** involving lateral observation of the full active range of cervical motion in the sagittal plane. Freeze frame capture of representative neutral, flexion and extension may be obtained and digitized.

3. **Left Posterior Oblique Flexion and Extension** permits observation of the right intervertebral foramina through flexion and extension. This flexion and extension positions of this examination are not performed with plain film and provide a unique opportunity to appreciate the patency of the foramina as well as the integrity of the capsular ligaments.

4. **Right Posterior Oblique Flexion and Extension** permits observation of the left intervertebral foramina through flexion and extension. Comparison of oblique studies may be helpful in cases of unilateral radicular complaints.

5. **Anterior/Posterior Lateral Flexion** permits observation of symmetry in cervical motion as well as coupled spinous rotation, which is normally expected.

6. **Anterior/Posterior Rotation** permits observation of symmetry in cervical rotation in the upper cervical spine and may reveal abnormalities associated with capsular ligament injury.

7. **Anterior/Posterior Open Mouth Lateral Flexion** permits observation of alar and accessory ligament function.

Clinical Utility of Videofluoroscopy

As a preface to this section, it is important to understand that the use of videofluoroscopy/digital videofluoroscopy should be performed following an appropriate history, clinical examination, plain film radiographs and/or other additional diagnostic modalities. Furthermore, under many circumstances, persistent symptoms despite undergoing a period of conservative management will typically form part of the clinical decision to utilize videofluoroscopy/digital videofluoroscopy.

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Among the early investigators of fluoroscopy whose studies are of relevance to chiropractic, Earl Rich[5] and Fred Illi[6] are considered pioneers. Videofluoroscopy has been used to observe and document the effects of cervical spine traction, evaluate cervical spine laminectomies, examine athletes presenting with pain, to assist in surgical planning, evaluate atlanto-axial rotatory fixation, examine the effects of cervical collars, characterize joint disorders in the cervical spine, study degenerative disease of the cervical spine and determine the effects of occipitalization and odontoid hypoplasia on spinal motion.[7-15]

Videoflouroscopy can demonstrate the differences in the motion patterns of normal and pathologic spines.[16] Schaff[17] described cases of instability of the upper cervical spine demonstrated on videofluoroscopic studies.

According to Ochs, "Cineradiography, using film or videotape, is shown in a study of 34 painful or injured necks to be a valuable diagnostic tool. It is useful in fracture management, diagnosis of instability and demonstration of solid healing. A video tape system featuring instant replay, clear image and low radiation exposure was found to be ideal for routine use."[18]

Videofluoroscopy permits evaluation of suspected soft-tissue injuries of the cervical spine by demonstrating active ranges of motion. It is reasonable to anticipate that abnormal motion will accelerate degenerative changes in the spine and will complicate the videofluoroscopic analysis. The videofluoroscopic study is of greatest value in the detection of abnormal motion in patients who show otherwise normal spines on standard roentgenograms and before degenerative changes have occurred.[14] The incidence of apophyseal joint abnormalities detected by videofluoroscopy is higher than that of plain roentgenograms. The videofluoroscopic study is of benefit in demonstrating either excessive or decreased mobility. It has proven to be of value in localizing the areas of abnormalities which correlate well with symptoms.[19]

Demonstrative Evidence of Trauma

Figure 2. Anterior subluxation of C2, C3 and C4 due to posterior longitudinal ligament disruption

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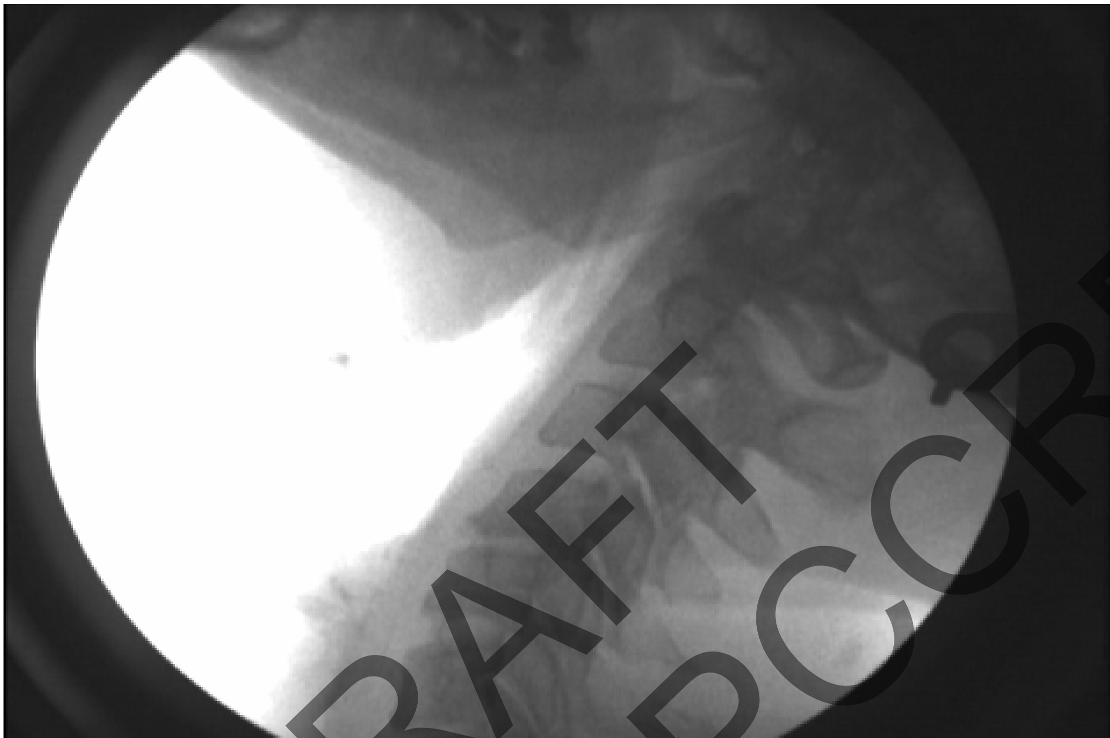

Figure 3. Posterior subluxation of C4 and C5 due to anterior longitudinal ligament disruption.

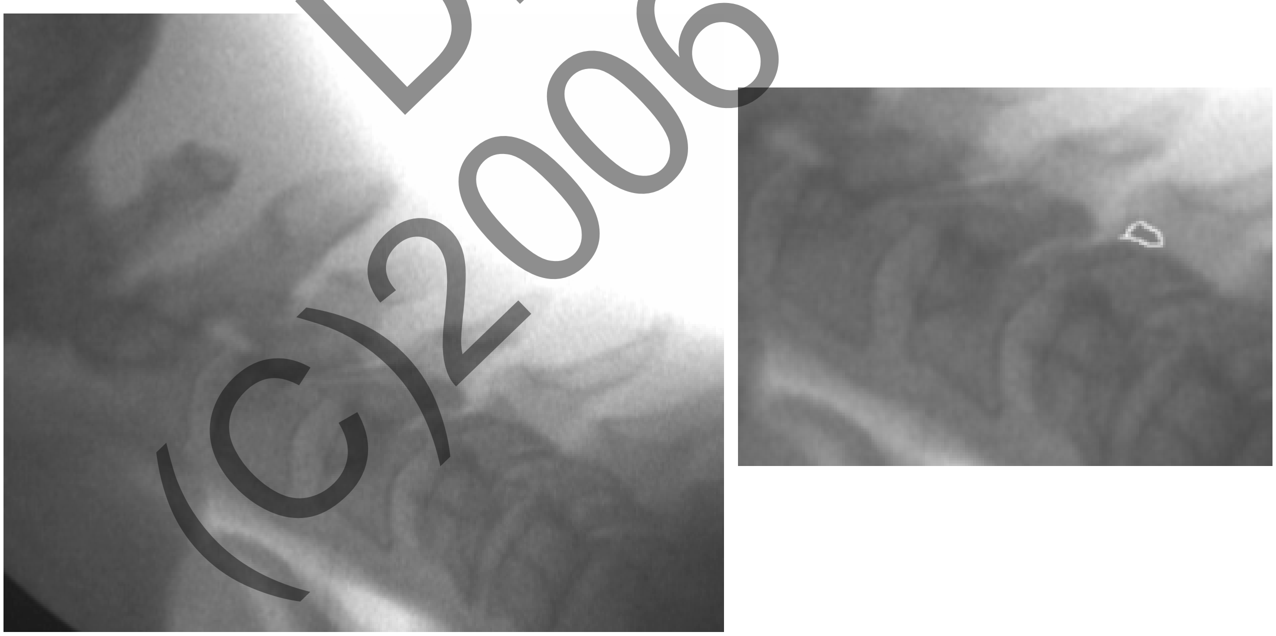

Figure 4. Fracture of C4 facet not detected on CT Scan.

Reliability of Measurement Methods

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The reliability of videofluoroscopic interpretation has been examined in the literature.[20-23,39] Croft studied the interexaminer reliability of the ability to distinguish between normal, hypomobile and hypermobile segments in 10 separate VF studies. Seven subjects were patients injured in auto collisions and three were uninjured "normal" subjects. There was good concordance between the 10 radiologists for the 10 VF studies of all cervical levels evaluated.

The reliability of videofluoroscopic measurement by computer assisted method has been reviewed by several investigators. In the case of video frame capture, measurement is performed on individual video frames and as such would be subject to the same reliability and validity as computer analysis of plain film roentgenograms. (Sections II and VIII) The reliability of fluoroscopic motion examinations analyzed by computer analysis has been reported.[24-27]

Validity

Studies of the use of videofluoroscopy have compared the utility of video fluoroscopy to plain film roentgenograms and reports have been made regarding the superiority of videofluoroscopy to plain film roentgenograms in the detection of some pathology of the cervical spine.[28-55] Videofluoroscopy studies have also been used to investigate normal and abnormal motion in the cervical spine.[56-64] Videofluoroscopy has also been used to produce data on the lumbar spine.[65-82]

In 1998, Okawa et al[94] obtained fluoroscopic lumbar sagittal motion videos in volunteers (n = 13) and in patients with chronic low back pain (n = 8) and degenerative spondylolisthesis (n = 8) while the subjects bent forward from a standing neutral position (eccentric motion) and then returned to the original position (concentric motion). They reported that segmental instability influenced the whole lumbar motion in patients with degenerative spondylolisthesis. The patients with chronic low back pain did not show a significant difference when compared with the volunteers.

In 2001, Takayanagi et al[95] studied 40 subjects (DS group) with degenerative L4-L5 segments compared to a control group of 20 subjects. The DS group was classified into 2 subgroups according to percentage of slip: DS group I, with a slip ≤ 15%; and DS group II, with a slip > 15%. Cineradiography was used while subjects flexed and extended in the sitting position. Motion analyses using cineradiography helped to explain the phenomena of lumbar spine kinematics. Based on continuous dynamic-motion analysis with cineradiography, large segmental angles and disordered motion pattern during the flexion-backward course in the DS group I was considered to be caused by segmental instability.

In 2004, Wong et al[96] studied 100 healthy volunteers, including 50 men and 50 women, in lumbar flexion and extension. Lumbar flexion-extension was assessed with an electrogoniometer and videofluoroscopy simultaneously. Intervertebral flexion-extension of each vertebral level was calculated. Radiologic images of the lumbar spine were captured during flexion-extension in 10 degrees intervals. A linear-linked pattern of the motions was observed in different genders and age groups. No statistically significant difference in the pattern of motion was found between genders. However, statistically significant difference in the slope of curves was found at all lumbar levels in subjects whose age was 51 years or older.

Roentgenometric and geometric appraisal of vertebral biomechanics may assist in the clinical decision making process. Along with the analyses associated with static spinal views in the neutral position, dynamic motion analysis of the spine is useful in the detection of ligamentous disruption and unstable motion segments. Occasionally, fractures are revealed that

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are not visible on plain film views. Identification of contraindications to direct applied forces (Chiropractic adjustments and physical rehab procedures) is an important clinical consideration in case management. Several threshold values for spinal instability have been published (Table1):

Table 1. Clinical Instability Thresholds for Different Spinal Regions.

Cervical spine instability	White and Panjabi [83]	3.5mm translation 11° rotation (flex/ext)
	AMA Guides 4th [84]	3.5mm translation 11° rotation (flex/ext)
	AMA Guides 5th [85]	3.5mm translation 11° Δ angulation /level on neutral
	Kranes et al [86]	1.7mm atlas lateral shift (in vivo) 2.2mm at 72" FFD (63)
Thoracic spine instability	AMA Guides 4th [84]	5mm translation 11° rotation (flex/ext)
	AMA Guides 5th [85]	2.5mm translation
Lumbar spine instability	AMA Guides 4th [84]	5mm translation 11° rotation (flex/ext) 15° rotation (flex/ext) L5/S1
	AMA Guides 5th [85]	4.5mm translation 15° rotation (flex/ext) L1-2, L2-3, L3-4 20° rotation (flex/ext) L4/L5 25° rotation (flex/ext) L5/SI

Videofluoroscopy in Chiropractic

The use of videofluoroscopy is recognized as an acceptable procedure in chiropractic practice by the following organizations in North America.

The American Chiropractic Association [87]

The Canadian Chiropractic Association [88]

The Mercy Center Consensus Conference [89]

The International Chiropractic Association [90]

The Council on Chiropractic Practice [91]

The American College of Chiropractic Radiology [87]

The College of Chiropractic Radiologists Canada [92]

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Summary

In summary, the production of videofluoroscopic, cineradiographic and digital motion X-ray images are a well accepted part of clinical chiropractic practice. These imaging techniques are irreplaceable in the chiropractic office with regards to clinical relevance. There is substantial data on the reliability, predictive validity, and clinical utility of these imaging techniques.

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